Series 1935, No. 22 Issued February 1942

Soil Survey

Tulsa County Oklahoma

By
E. W. KNOBEL
United States Department of Agriculture, in Charge
and
O. H. BRENSING
Oklahoma Agricultural Experiment Station

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PLANT INDUSTRY
In cooperation with the
Oklahoma Agricultural Experiment Station

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SOIL SURVEY OF TULSA COUNTY, OKLAHOMA

By E. W. KNOBEL, Soil Survey Division,[1] Bureau of Chemistry and Soils, United States Department of Agriculture, in Charge, and O. H. BRENSING, Oklahoma Agricultural Experiment Station

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United States Department of Agriculture in Cooperation with the Oklahoma Agricultural Experiment Station

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COUNTY SURVEYED

Tulsa County is in northeastern Oklahoma (fig. 1), the fourth county from the eastern State line and the second county from the northern State line. In outline it is irregular, resembling a capital T turned sideways to the right. Tulsa, the county seat, is 118 miles by rail and 100 miles by air line northeast of Oklahoma City. The area of the county is 585 square miles, or 374,400 acres.

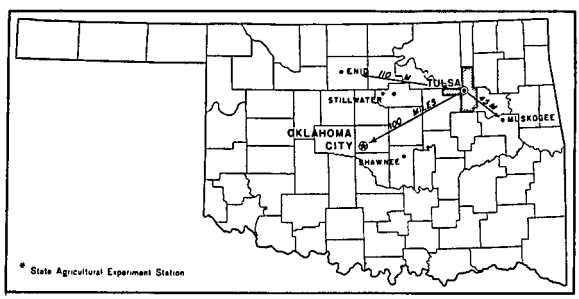

FIGURE 1.—Sketch map showing location of Tulsa County, Okla.

[1] The Soil Survey Division was transferred to the Bureau of Plant Industry July 1, 1939.

Tulsa County lies mainly within the Prairie soil region of the United States and within the Osage Plains section of the Central Lowland physiographic province, which is just east of the Great Plains province.

The northern, east-central, and southern parts of the county are only slightly to moderately dissected and are the product of the geological erosion of a once smooth-lying to gently undulating plain. Above this plain rise a few rather conspicuous sandstone and shale hills in the northwestern part, two small hills known as Twin Mounds in the southern part, and a few square miles of rather rough terrain carved from sandstone in the extreme southeastern part.

The rectangular western extension of the county is more deeply dissected than the rest because the Arkansas River, which enters the northwestern extremity of this extension, has facilitated the cutting of local drainage channels to base level in a comparatively high country. At about the center of the county, near Tulsa, the Arkansas River changes its course from eastward to southeastward. Along this part of its course dissection is not pronounced, but along the belt, ranging from 2 to 5 miles in width, on either side of the Arkansas River Valley proper, dissection is more pronounced than farther back in the more gently undulating plains country. A few escarpments divide the gently undulating prairies from the broken or more rolling areas in places. The area in the western extension of the county, lying south of the Arkansas River, is, for the most part, covered with many rugged sandstone-capped hills, which reach their maximum height near the town of Red Fork in T. 19 N., R. 12 E., where they are approximately 200 feet above the surrounding plain. Farther west and south of Sand Springs are several square miles of rough terrain in which the embedded limestone underlying the higher sandstone-capped hills protrudes in massive outcrops, especially noticeable along the bluffs of the Arkansas River.

In this county the Arkansas River Valley is narrow. Ordinarily the width ranges from 1 to 2 miles, but in some places it is less than a mile, and in other places it is more than 2 miles. The valley is widest in the vicinities of Bixby, Jenks, and Leonard. The stream reached base level long ago, and during recent years deposits of coarse sand and small pebbles apparently are raising the old channel to a higher level. Similar aggradation is taking place in several of the larger rivers of the country. When the river flow is normal, approximately one-half of the main river channel is filled with irregular and constantly changing barren sand bars.

The highest point in the county, 1,017 feet above sea level, is near the center of sec. 21, T. 19 N., R. 10 E., and the lowest point, 550 feet, is near the southeastern corner of sec. 25, T. 17 N., R. 14 E., where the Arkansas River crosses the eastern county line into Wagoner County. The elevation at Tulsa is 804 feet.[2]

Approximately half of the drainage of the county is effected through many short tributaries leading directly into the Arkansas River. Among the larger streams are Bakers, Snake, Posey, Coal, Nickel,

[2] GANNETT, HENRY. A DICTIONARY OF ALTITUDES IN THE UNITED STATES. U. S. Geol. Survey Bul. 274, ed. 4, 1072 pp. 1906.

Polecat, Haikey, Duck, Fisher, Anderson, and Shell Creeks. The east-central part is drained mainly by Mingo Creek, which flows northward about 12 miles, emptying into Bird Creek. Bird Creek, a permanent stream, enters the northwestern corner of the county, flows southward about 12 miles, thence eastward to the confluence of Mingo Creek, and thence into Rogers County, where it empties into the Verdigris River. Bird Creek is rather sluggish, as evidenced by the numerous meanderings, and a large part of the bottom land along this stream has imperfect surface drainage and underdrainage. Surface drainage as a whole is good, but underdrainage on many of the very smooth upland areas is more or less imperfect because some of the soils have very heavy almost impervious subsoils.

The native vegetation comprises both forest and prairie growth. The smooth prairie land originally supported a heavy growth of coarse bunchgrasses with a less abundant and more varied growth of buffalo and grama grasses. The grama grasses are largely such species as blue grama (*Bouteloua gracilis*), hairy grama (*B. hirsuta*), and side-oats grama (*B. curtipendula*), and the bunchgrasses consist mainly of bluejoint turkeyfoot or big bluestem (*Andropogon furcatus*), prairie beardgrass or little bluestem (*A. scoparius*), broomsedge (*A. virginicus*), and switchgrass (*Panicum virgatum*). On prairie land of low productiveness certain species of three-awn grasses (*Aristida* spp.) are common. Poorly drained areas support a cover of water sedges and saltgrass. On the thin sloping prairie soils the vegetative cover is not so uniformly abundant and consists mainly of the coarser grasses in association with sumac and other shrubs and many species of weeds. During spring a profusion of wild flowers spreads over both prairie and forested areas.

Originally about one-third of the county was forested. All the stream bottoms were covered with a moderate to rather thick tree growth, some of which still remains. These trees are chiefly pecan, black oak, pin oak, red oak, elm, hickory, hackberry, ash, cottonwood, sycamore, willow, wild cherry, wild plum, dogwood, and hawthorn. Wild grape and buckbrush are common. On some of the high terrace lands adjoining the Arkansas River bottom the forest growth is mainly black oak, and on the lower slopes the trees are largely black oak, red oak, white oak, post oak, hickory, elm, and sycamore. In the southeastern corner and western part of the county the terrain is rough and rocky and has a forest growth consisting mainly of blackjack oak and post oak, with scattered elm, hickory, and a few cedars along the limestone ledges.

That part of Oklahoma in which Tulsa County is located was formerly occupied by the Cherokee and Creek Indian Nations. The east-west boundary line between these nations extended through Tulsa County along the northern edge of the western extension of the county and thence due east through the city of Tulsa. The Creek Nation occupied the territory south of this boundary and the Cherokee Nation the territory to the north.

Tulsa County was organized in 1907 from parts of the Cherokee and Creek Nations; later, in 1909, a part of Wagoner County and, in 1918, a part of Rogers County were annexed. Most of the early settlers came from adjoining or nearby States.

The increase in population in Tulsa County since its organization in 1907 has been very rapid. The city of Tulsa was named for a former Creek Indian clan and was one of the original towns of the Indian Territory. According to the Federal census, the city's population increased from 1,390 in 1900 to 18,182 in 1910, to 72,075 in 1920, and to 141,258 in 1930. The populations of other incorporated towns in 1930 were as follows: Sand Springs, 6,674; Collinsville, 2,249; Broken Arrow, 1,964; Skiatook, 1,789, of which 1,152 resided in Tulsa County and 637 in Osage County; Jenks, 1,110; Bixby, 1,251; Dawson, 842; and Sperry, 563. According to the Federal census, the total urban population in the county in 1910 was only 18,182, but in 1930 it had increased to 147,932. The total rural population in 1910 was 16,813, increasing to 39,642 in 1930, which is equivalent to an average density of rural population of 67.8 persons per square mile. Of the total rural population in 1930 the census lists 12,118 as rural farm and 27,524 as rural nonfarm. The 1935 census reports the farm population on January 1 as 16,547. The actual farm population per square mile was 20.7 persons in 1930, and 28.3 in 1935. Because of the large population of Tulsa and the smaller towns and the general scarcity of population in the hilly and rugged parts of the county, the population is very unevenly distributed, but the smooth, tillable parts of the county are fairly uniformly populated.

Tulsa is the chief market; more distant markets are Oklahoma City, Kansas City, St. Louis, Denver, and Wichita. Considerable quantities of early vegetables and fruits are hauled in trucks to these and other cities, where prices are higher.

Fast automobile and motortruck transportation is accessible to practically all parts of the county, and good highways connect all cities. Most of the county roads follow section lines except in a few of the rougher parts of the western extension. The county roads are well graded and kept in better repair than those in many counties of the State. In 1930 the county had 206.75 miles of paved roads. United States Highways Nos. 64, 66, 75, and 169 form a close network of all-weather roads, most of which connect Tulsa with other points. Adequate rail transportation facilities are furnished by the Atchison, Topeka & Santa Fe Railway, the Missouri-Kansas-Texas Railroad, the Midland Valley Railroad, the St. Louis-San Francisco Railway, and an electric line known as the Sapulpa Union Railway, connecting Tulsa with Sapulpa to the southwest.

Rural mail routes and telephone service are available to practically all parts of the county. School facilities are excellent. Although less than 20 strictly rural schools are in the county, a few of which are consolidated, many schools are in small towns and subdivisions. The school bus is in common use. The city of Tulsa has 34 public, 2 parochial, and several private schools, besides Tulsa University.

Inasmuch as Tulsa has been called the oil capital of the world, much interest is centered in the oil industry. During the spectacular rise of Tulsa, three major oil companies established large oil refineries near Tulsa in the Arkansas River Valley, and several large storage-tank fields lie within a few miles of the city. Since the discovery of oil in Tulsa County in 1901, a considerable part of the county, in a number of small fields, has proved to be productive of oil. In 1935, 1,432,430

barrels, or an average of 119,369 barrels monthly, were produced.[3] It is considered highly probable that within the next few decades the underlying oil supply, especially in Tulsa County, will become exhausted. In that event it seems likely that much more attention will be given to the production of crops instead of oil. The conservation of the soil resources, therefore, is important, and, because of the high erodibility of the soils in this section, far more care than that shown up to the present will be necessary if the soil resources are to endure.

Strip coal mining has been in progress for the last 30 years. The most extensive workings have been developed near Dawson and Collinsville.

Good drinking water is obtained on most farms at a depth ranging from 15 to 80 feet, but the water obtained on the flat prairie lands having heavy shale or clay subsoils ordinarily contains considerable gypsum and sodium salts and is not so healthful or palatable as that obtained on the sandy soils with sandy clay subsoils. Many farmers have small dams across drainageways, thereby forming reservoirs to store water for livestock. Many more could be constructed and utilized as soil-saving dams, because gullying is active on land bordering many of the small drainageways. Tulsa has an abundance of excellent water, which is piped from Lake Spavinaw in Rogers County. This reservoir was completed in 1924 at a cost of $9,344,000. It impounds sufficient water for more than 2 years' supply without replenishment.

CLIMATE

The climate of Tulsa County is continental and subject to sudden wide changes in temperature. The humidity is rather high in comparison with that in western Oklahoma or Colorado.

During sudden periods of cold weather, the temperature, even though it may be several degrees above zero, is more penetrating and sensibly colder than zero or subzero temperatures in Colorado or other high semiarid sections. These cold waves, which usually last from 3 to 5 days, cause some inconvenience in caring for livestock, although severe injury to them is rare. Ordinarily the winters are comparatively mild. A few light snowfalls occur each winter, an average of 9.6 inches, but the snow invariably melts in a few days. Where winter pasture has been provided, cattle forage nearly all of the winter.

The summers are long and hot, but the hottest days are tempered by prevailing southern breezes, which occur during all months except December, January, and February. The velocity of wind is highest during the warmer part of the day and recedes in the evening and night. Ordinarily the nights are fairly cool.

Spring and fall are cool but rather windy and may be either very dry or extremely wet. As a rule, the fall weather is pleasant. During the planting season, high winds sometimes cause considerable damage to field crops from wind erosion. Tornadoes and hailstorms are rare.

About two-thirds of the average annual rainfall occurs during the planting and growing season, between April 1 and September 30. Ordinarily the amount is adequate and sufficiently well distributed to provide the necessary moisture for spring crops. Some of the soils

[3] Oil and Gas Jour. 34 (37) : 87. 1936.

with impervious subsoils or shallow surface soils, however, do not allow deep root penetration, and during July and August several crops, especially corn, may be seriously injured from lack of available moisture. Owing to the dry windy weather, usually following local sudden summer showers, the land under cultivation dries rapidly, and most crops suffer because of the high evaporation rate rather than from insufficient rainfall. Some of the heavier textured and claypan soils have both imperfect surface drainage and underdrainage and often are too wet for satisfactory cultivation during May and June.

The average length of the frost-free period is 219 days, or from March 26, the average date of the latest frost, to October 31, the average date of the earliest. The date of the latest spring frost on record is April 17 and of the earliest is October 9. The frost-free period gives ample time for the various crops adapted to the soils and climatic conditions to mature. Orchard crops, such as peaches, are rather uncertain, owing to late killing frosts, and this accounts largely for the scarcity of commercial orchards in the county.

Table 1, compiled from records of the United States Weather Bureau station at Tulsa, gives the normal monthly, seasonal, and annual temperature and precipitation, which are representative of conditions over Tulsa County.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Tulsa, Tulsa County, Okla.*

[Elevation, 700 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1896)	Total amount for the wettest year (1915)	Snow, average depth
	°F.	°F.	°F.	*Inches*	*Inches*	*Inches*	*Inches*
December	39.9	78	−3	1.98	0.90	1.05	1.3
January	37.0	82	−16	1.91	.50	2.24	3.2
February	41.0	90	−15	1.66	.30	4.93	3.3
Winter	39.3	90	−16	5.55	1.70	8.22	7.8
March	51.2	99	6	3.02	1.30	4.42	1.6
April	60.5	98	22	4.13	1.60	7.76	(1)
May	68.4	98	32	5.23	5.90	7.40	0
Spring	60.0	99	6	12.38	8.80	19.58	1.6
June	77.8	108	49	4.88	4.10	7.05	0
July	82.0	108	53	3.31	.60	7.70	0
August	82 1	111	48	3.21	0	10.56	0
Summer	80.6	111	48	11.40	4.70	25.31	0
September	75.0	107	37	3.32	1.50	6.39	0
October	62.2	97	15	3.68	4.60	1.90	(1)
November	50.8	89	13	2.48	2.50	1.42	.2
Fall	62.7	107	13	9.48	8.60	9.71	.2
Year	60.7	111	−16	38.81	23.80	62.82	9.6

[1] Trace.

AGRICULTURAL HISTORY AND STATISTICS

Tulsa County lies within the country originally allotted to the Creek and Cherokee Nations. Agricultural pursuits were very limited before 1887. A few patches of corn and a few vegetables were grown and a

small number of cattle were grazed, but subsistence was obtained chiefly by hunting and fishing. A few white squatters, through agreement with the Indians, grazed cattle on the prairie grasses during part of the year.

After the inrush of settlers in April 1887, agricultural development began in earnest. A branch of the Santa Fe Railway, connecting Arkansas City, Kans., and Fort Worth, Tex., completed in 1887, extended through what is now Tulsa County and greatly facilitated early development. The settlers migrating from States to the north and east planted corn, wheat, oats, rye, and potatoes, and those from the South planted cotton, corn, and sorghums. Their cultural methods were as varied as the number of farming sections represented. Each settler was permitted to homestead only 160 acres, but many kept some cattle and broke only a part of their holdings.

Several marked changes have come about since the early days. The former vast expanse of tall prairie grasses is now almost extinct, the newly broken dark-colored surface soil is not only thinner but not nearly so dark, and the general effects of erosion are very pronounced, especially on the sloping lands. In driving over the county a casual observer is impressed by the close network of fast all-weather automobile and truck roads; numerous oil wells, oil-tank fields, and refineries; and the skyscrapers of Tulsa looming on the horizon from any vantage point within the county—developments that have taken place within three decades.

The trend in production of crops may be traced from the data given in table 2. In interpreting these data it should be remembered that about 12,800 additional acres were included between the census of 1910 and that of 1920.

TABLE 2.—*Acreage of the principal crops in Tulsa County, Okla., in stated years*

Crop	1909	1919	1929	1934	Crop	1909	1919	1929	1934
	Acres	*Acres*	*Acres*	*Acres*		*Acres*	*Acres*	*Acres*	*Acres*
Corn	90,397	23,354	49,040	19,743	Sorghums for silage, hay, and fodder	-------	[3] 2,838	2,026	9,418
Oats	1,977	34,673	9,775	20,809	Grain sorghums	163	971	3,043	5,149
Wheat	1,059	35,184	2,772	2,673	Potatoes	665	229	782	1,150
Cotton	4,398	7,530	14,552	15,159	Sweetpotatoes	68	385	651	594
Tame hay [1]	870	5,442	5,437	19,753	Vegetables for sale	456	177	1,744	3,234
Alfalfa	146	3,839	3,189	4,374					
Wild hay	18,595	12,150	9,246	([2])					

[1] Includes timothy, clover, all cultivated grasses, grains cut green, and all legumes.
[2] Included in tame hay.
[3] For forage only.

The diversity of agriculture has been greatly influenced by the rapid growth of the city of Tulsa.

Corn has been the leading crop from the beginning. It was surpassed in acreage by oats or wheat in some years, notably during a short post-war period. Cotton has always been one of the leading cash crops, but the acreage and production have not been so high as in many other counties of the State. Wheat and oats have proved successful. The soils best adapted to wheat and other small grains, however, do not predominate, and many other crops are grown to greater advantage.

Little alfalfa was grown in 1909, but by 1934 alfalfa was produced on 4,374 acres. Other tame or cultivated grasses, such as Sudan grass, Bermuda grass, and various grain sorghums, as well as silage crops, have a promising future. Much less wild hay is cut than formerly, although the acreage is still large.

Garden and truck crops have rapidly increased in importance. Market-garden vegetables were grown on 1,744 acres in 1929 and on 3,234 acres in 1934.

Several nurseries and large commercial orchards are located in the county. There were 49,791 peach trees, 9,756 apple trees, 27,733 pecan trees, and 66,550 grapevines in 1930, and 50,990 peach trees, 12,454 apple trees, and 82,335 grapevines in 1935. Pecan trees were not reported in the 1935 census.

Commercial fertilizers are not extensively used, but their use is increasing, owing to an increase in the number of truck farms and to the fact that the older cultivated fields show a general decline in crop yields. In 1929 only 2.5 percent of the farms, or 61 out of 2,489, used commercial fertilizer, at an average cost of $63.41 a farm. Considerable experimentation will be necessary to determine the proper fertilizer requirement for any particular crop on the many different soils. Phosphatic fertilizers, such as bone meal, superphosphate, rock phosphate, and some balanced fertilizers, are the chief fertilizers used. Ordinarily, about 100 pounds of phosphatic fertilizer an acre has proved beneficial in keeping the soil in a productive condition for oats, wheat, and barley.

During recent years the use of ground limestone to correct soil acidity has been on the increase. An abundance of limestone of high purity exists in the county and can be obtained at reasonable prices at the several crushing plants. The common acre application is from 2 to 3 tons. Fine-ground limestone that passes through a 100-mesh sieve is the preferred form, as the lime is more readily available.

The hire of labor was reported in 1929 by 882, or 35.4 percent, of the farms, at a total cost of $418,361, or $474.33 per farm reporting. Ordinarily, both white and Negro laborers are plentiful. Some laborers are hired in caring for orchard, truck, or small-grain crops, and some are hired by the month on dairy and other farms.

A considerable expenditure is made for feed. In 1929, 1,236, or 49.7 percent, of the farms reported its purchase at a total cost of $549,298, or $444.41 per farm reporting.

The average farm is moderately well improved and equipped, especially if located on good tillable land. The farm buildings usually consist of a one-story frame house, garage, chicken house, and a small or medium-sized barn. Many of the farms in or close to the richer bottom land have two-story dwellings, large dairy barns, and possibly one or more silos, and are supplied with gas and electricity. Most of the farms in the more rugged parts of the county, however, have small dwellings and poor to fair buildings and equipment. The better farmers provide shelter for their farm machinery, but many leave part of their machinery outside. Practically all of the farms and ranches have one or more windmills for supplying water. The livestock farmers generally have small dams conveniently located as

a supplementary means of supplying water for livestock during the hot and droughty part of the summer.

Low, rectangular, galvanized sheds on many farm tracts house the oil-pumping machinery that is connected to several oil wells on the tract. Many of these have been in operation for several years, and the manager of such wells, who usually lives on the property, may or may not own the land or be engaged in active farming. These wells, in general, have had a demoralizing effect on agriculture on the land about them.

The average size of farms has decreased steadily from 139.3 acres in 1910 to 87.3 acres in 1935, according to the Federal census. The total number of farms, on the other hand, has increased from 1,900 in 1910 to 3,119 in 1935. The rapid growth of Tulsa and the recent depression are important factors in this change. Of the total area of the county, 73.2 percent was in farms in 1910, 61.9 percent in 1930, and 72.7 percent in 1935. The land available for crops in 1934 was 186,982 acres, or slightly less than one-half of the total area of the county. This included 106,227 acres on which crops were harvested, 20,500 acres on which crops were a failure, 9,401 acres of idle or fallow land, and 50,854 acres of plowable pasture. In addition, 40,038 acres were in woodland pasture, 23,032 acres in other pasture, 7,416 acres in woodland not pastured, and 14,864 acres represented all other land in farms.

According to the 1935 census, 40 percent of the farms were operated by owners, 58.7 percent by tenants, and 1.3 percent by managers. Negroes operated 253 farms, or 8.1 percent.

The most common form of rental is the crop-share plan. Most of the cultivated rented land is leased on a share basis, under which the tenant furnishes all equipment, pays all expenses of producing the crops, and delivers one-third of the grain and one-fourth of the cotton crop to the landowner. Some of the land is rented for cash, the amount paid depending on the type of soil, general improvements, and accessibility to markets. As a rule, either hay or pasture land is rented for cash, and some of the Arkansas River bottom land is so rented.

According to the 1930 census, the average value of all property per farm was $11,679. This represented a valuation of 77 percent in land, 14.6 percent in buildings, 3.1 percent in implements, and 5.3 percent in domestic animals. The average value per acre, including buildings and improvements, was $29.19 in 1910, $86.62 in 1920, and $114.90 in 1930. The rapid and extensive growth of Tulsa within a comparatively small county is the chief factor that has had such a marked influence on the average acre value of farm property. Moreover, the fact that many farms have a number of producing oil wells is also significant, as much of the land, either arable or nonarable, has a speculative value.

Table 3 shows the values of various agricultural commodities during 1929.

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TABLE 3.—*Value of various agricultural commodities, by classes, in Tulsa County, Okla., in 1929*

Crops and products	Value	Livestock and products	Value
Cereals	$827,843	Dairy products sold	$879,732
All other grains and seeds	22,568	Poultry raised and eggs produced	482,716
Hay and forage	208,948	Wool and mohair	378
Vegetables (including potatoes and sweetpotatoes)	288,432	Total	1,362,826
Fruits and nuts	97,205		
All other field crops	487,937		
Farm garden vegetables (excluding potatoes and sweetpotatoes) for home use	94,927		
Forest products cut on farms for home use and for sale	14,778		
Nursery and greenhouse products	149,778		
Total	2,192,416		

There were 30,382 cattle in the county on January 1, 1935, according to the Federal census. Jersey is the predominating dairy breed, but some Holstein-Friesian, Guernsey, and dual-purpose cattle are kept for dairy purposes. The Hereford, Shorthorn, and Durham are the chief beef breeds, but many of the farmers own cattle of mixed breeding. The latter are more commonly grazed on the rougher forested or rocky parts of the county.

The number of cows milked in 1929 was 9,355, and the production of milk was 4,942,032 gallons. This was marketed mainly in the form of fluid milk, of which 3,019,397 gallons, valued at $754,849, were sold. The production of milk increased to 5,486,149 gallons in 1934, when 12,187 cows and heifers were milked. Owing to the steady growth of the city of Tulsa and the accessible markets for farm commodities, dairying has a promising future. Numerous milk routes are in operation, and a ready market is available for fluid milk, butter, cheese, and other dairy products.

Considerable income is derived from the raising of poultry. The Federal census reported 265,458 chickens raised in 1929, valued at $191,130, of which 93,377 were sold alive or dressed. In the same year 1,096,800 dozens of eggs, valued at $285,168, were produced, of which 721,698 dozens, valued at $187,641, were sold. In 1934, 221,425 chickens were raised and 701,100 dozens of eggs produced. Tulsa affords an excellent market for eggs, fryers, and fattened poultry. Several commercial hatcheries are operated and supply young chicks to both local and outside territory. Plymouth Rock, Leghorn, and Rhode Island Red are the most popular breeds. Most farmers have small flocks ranging from 50 to 100 or more chickens, and those engaged in the business on a commercial basis have flocks of several hundred to a thousand or more.

There were 12,746 hogs on the farms on January 1, 1935, a smaller number than that reported by the 1930 census. Most of the hogs are Poland China, Duroc-Jersey, and Chester White, or crosses of these breeds.

Horses numbered 4,754 on January 1, 1935, and mules 2,713. Most of the horses and mules range from rather small to medium in size, especially those of local strains, but larger animals, including mules and Percheron draft horses, have been imported, chiefly from Missouri and Kansas. Sheep numbered 1,179 in 1935, but sheep raising is not important in this section of the State.

The present condition of agriculture in the county as a whole is good, owing to the gradual recovery following the depression and the excellent local market. Although little attention was paid to soil-improvement methods or erosion control prior to 1934, much interest has recently been shown in soil conservation, as evidenced by the numerous terraces constructed in fields and improved methods for the disposal of surplus run-off.

SOIL-SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field.

The soils are examined systematically in many locations. Test pits are dug, borings are made, and exposures, such as those in road or railroad cuts, are studied. Each excavation exposes a series of distinct soil layers or horizons called, collectively, the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is studied in detail; and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The reaction of the soil[4] and its content of lime and salts are determined by simple tests.[5] Drainage, both internal and external, and other external features, such as relief or lay of the land, are taken into consideration, and the interrelation of soils and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, special emphasis being given to those features influencing the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics soils are grouped into mapping units. The three principal ones are (1) series, (2) type, and (3) phase. Areas of land, such as coastal beach or bare rocky mountainsides, that have no true soil are called (4) miscellaneous land types.

The most important group is the series, which includes soils having the same genetic horizons, similar in their important characteristics and arrangement in the soil profile, and developed from a particular type of parent material. Thus, the series includes soils having essentially the same color, structure, and other important internal characteristics and the same natural drainage conditions and range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The soil series are given names of places or geographic features near which they were first found. Thus, Bates, Parsons, and Verdigris are names of important soil series in this county.

Within a soil series are one or more soil types, defined according to the texture of the upper part of the soil. Thus, the class name of the soil texture, such as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, and clay, is added to the series name to give the complete name of the soil type. For example, Bates silt loam and Bates fine sandy loam are soil types within the Bates series. Except for the texture of the surface soil, these soil types

[4] The reaction of the soil is its degree of acidity or alkalinity expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality, higher values indicate alkalinity, and lower values indicate acidity.

[5] The total content of readily soluble salts is determined by the use of the electrolytic bridge. Phenolphthalein solution is used to detect a strong alkaline reaction.

have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the soil unit to which agronomic data are definitely related.

A phase of a soil type is a variation within the type, which differs from the type in some minor soil characteristic that may have practical significance. Differences in relief, stoniness, and the degree of accelerated erosion are frequently shown as phases. For example, within the normal range of relief for certain soil types, some areas are adapted to the use of machinery and the growth of cultivated crops and others are not. Even though there may be no important difference in the soil itself or in its capability for the growth of native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated crops. In such an instance the more sloping parts of the soil type may be segregated on the map as a sloping or hilly phase. Similarly, soils having differences in stoniness may be mapped as phases, even though these differences are not reflected in the character of the soil or in the growth of native plants.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types, phases, and miscellaneous land types, in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

SOILS AND CROPS

Although Tulsa County includes a comparatively small area, it has a wide diversity of soils. The long weathering of several geological formations or parent rock materials, including very thick to very thin limestone, sandstone, shaly sandstone, and shale, on relief ranging between two extremes—almost level and very steep—has given rise to a large number of arable and nonarable soils. On very high old stream terraces soils have developed from ancient alluvium transported from western areas by floodwaters of streams. Other streams besides the Arkansas River that enter the county or rise within it drain either calcareous or noncalcareous uplands or both and have, during past overflow stages, accumulated alluvial sediments, forming both well-drained and imperfectly drained bottomland soils, thus increasing the number of soils in this county. The exceptionally high overflow deposits of the Arkansas River form a very irregular belt of both level and rolling terrace land on each side of the river. In this county the belt is continuous on the northern side of the river but very patchy and discontinuous on the southern side, owing to the former thin deposits on the many higher adjoining upland slopes and their subsequent removal by erosion. These soils have the appearance of upland soils but are readily identified by the lime-bearing red substratum transported mainly from the "Red Beds" of western Oklahoma, Colorado, and Kansas. Because of extreme variations of past river currents, the texture of both surface soils and subsoils, color, relief, productivity, and adaptation of the resulting soils vary considerably.

The appearance of a rather flat basinlike valley in the east-central part of the county adjoining Mingo Creek and the existence of soils having comparatively deep dark-colored surface soils indicate that a considerable part of this valley, as well as Bird Creek Valley, may possibly have been an inland lake or land covered with backset waters at the highest stage of overflow along the Arkansas River.

A comparatively small part of the county, mainly the western part and, in places, the southeastern part, consists of very rolling to steep forested terrain. Here, sandstone material predominates, although some shale material occurs, and ledges of limestone are numerous in places along the Arkansas River bluffs or deep ravines leading thereto. Such land is generally too rough and stony for cultivation and is utilized chiefly for grazing. Another rolling rocky area underlain by shale is in the northwestern part of the county, which is treeless and supports a good grass cover; and a few scattered similar patches are in the southwestern part.

The fairly smooth, undulating to slightly rolling upland in the northern, central, and southern sections of the county cover the greater part of its area. This land is derived from shales, fine-grained sandstone, and some limestone. The weathered limestone parent material has given rise to dark-brown and reddish-brown arable soils, as well as similarly colored nonarable pasture land. These limestone soils occur in various parts of the county, mainly in the east-central part. The smooth-lying Prairie soils formed from shales, fine-grained sandstone, limestone, or high-terrace alluvium are the most extensive soils in this county and are well distributed. Their proper care and agricultural utilization largely determine the general prosperity of the inhabitants.

Practically all of the smooth Prairie soils have been developed under an original cover of tall prairie grasses. Large quantities of organic matter, in some places as much as 5 or 6 percent, have accumulated in the surface soil from the decay of these grasses, especially the roots, and have imparted the generally dark color to that layer. The high organic-matter content increases the ability of the soil to absorb the sun's heat, to maintain a uniform temperature, and particularly to retain moisture, thereby aiding crops to resist drought, materially increasing the stability of the mineral particles, and helping to maintain a desirable tilth. Moreover, organic matter is the chief source of nitrogen, one of the most important plant nutrients for growing crops. Continual cropping gradually depletes the store of nitrogen, phosphorus, and organic matter, but the most severe loss of these plant nutrients in this county is very largely through erosion of the surface soil under improper methods of cultivation.

Under the prevailing climate the annual average precipitation of 38.81 inches is sufficient to remove lime (calcium carbonate) to a depth of 3 to 4 feet in the limestone soils and 4 to 6 feet in other smooth-lying Prairie soils, but only small traces of lime originally existed in the Bates or Parsons soils. Because of the prevailing heavy claypan of the Parsons soils the surface soil is more acid than that of other upland soils but in many places is about neutral at a

depth of 3 to 4 feet. The Bates soils generally range from slightly acid to neutral in the lower part of the subsoil but are not too acid to produce a stand of alfalfa, especially where the soil has been inoculated.

During the 30 years prior to 1935, the productivity of the upland soils has rapidly declined, owing largely to continuous cropping without restoration of plant nutrients by the general use of legumes, commercial fertilizers, crop rotations, or measures to control erosion. Even some of the uncultivated plowable fields have suffered from erosion because of the careless disposal of oil and salt water from oil wells. The loss of phosphorus, nitrogen, and organic matter is indicated by lower yields of various crops and by chemical analyses of many soils at the Oklahoma Agricultural and Mechanical College. Most of the soils are developed from fine-grained sandstone, limestone, or shale, or a combination of these soil-forming materials. They are highly susceptible to erosion, as the average annual rainfall is sufficient to cause severe washing of soil on slopes that have little or no vegetation or are devoted to clean-tilled crops.

Prior to 1933, soil terracing and contour farming were almost unknown in this county, but the depression hastened both State and Federal agencies in taking an active part in problems of soil erosion and land conservation. At the close of 1935, rapid strides had been made in the construction of terraces and the practice of contour farming, and considerable interest was shown in the construction of soil-saving dams and the baffling of the road ditches. Such land conservation work will necessarily take a number of years to be properly carried out, and much care and foresight will be necessary, especially during the first few years.

The principal systems of agriculture are (1) general farming, or the production both of livestock and of grain, hay, and forage crops best suited to the locality or particular farm; (2) truck farming, including various early vegetables and truck crops, fruits, and berries, mainly for the local market; (3) livestock and dairy farming for the production of livestock, including poultry and dairy products used largely in the local market; and (4) the production and grazing of range beef cattle on a few ranches and large livestock farms.

Approximately 50 percent or more of Tulsa County is covered with arable soils that are topographically suitable for cultivation. The field crops grown are similar to those of other counties of eastern Oklahoma adjoining the Arkansas River, but the quantities and kinds of truck crops are greatly influenced by the nearby market at Tulsa. Truck crops, therefore, are more important within several miles of Tulsa, especially along the Arkansas River. All kinds of early vegetables, berries, melons, and potatoes grow very successfully on the medium to very fine sandy-textured soils of the Lonoke and Yahola series. The heavier textured soils of these series and of the Miller series, which have good surface drainage but are not so favorable for trucking, are used to good advantage in growing corn, cotton, and alfalfa. Alfalfa is increasingly important, because of its ready sale and its use in rebuilding soils that are in an impoverished condition. This crop is grown on all the well-drained soils of the bottom lands and to some extent on the soils of the uplands having

friable crumbly subsoils, such as soils of the Bates, Summit, Teller, and Stidham series. Cotton is grown on soils of both the bottom lands and the uplands, but most successfully on some of the Miller, Lonoke, Verdigris, Yahola, Teller, and Bates soils. Small grains, such as wheat, oats, and barley, grow better on the Parsons soils than do many other crops, because of their shallow root system, early maturity, and tolerance of acid soil conditions. Various sorghums succeed on these soils, because of their resistance to drought. Corn is grown on practically all of the soils, but it does better on the deeper well-drained alluvial soils. The dark soils of the uplands, such as some types of the Stidham, Teller, and Bates series, are also well suited to corn, because of their friable subsoils and moderate content of organic matter in the surface soils. Orchard crops, including grapes, peaches, apples, cherries, and pears, do particularly well on the high-terrace soils of the Stidham and Teller series, because of the underlying permeable subsoils, which allow deep penetration of roots. Some well-drained soils of the bottom lands are also very suitable for such crops.

Figure 2 shows the general distribution of the major soil areas in the county.

According to the 1935 census, approximately 36.3 percent of the land in the county represents cropland, but economic factors, droughty years, and prices of farm commodities cause more or less variation from year to year in the acreages and relative importance of principal crops. In 1934 the chief crops, in order of acreage, were oats, hay and fodder, corn, cotton, sorghums for silage, grain sorghums, market-garden vegetables, and wheat, which were harvested on 15.3, 14.5, 11.1, 6.9, 3.8, 2.4, and 2 percent, respectively, of the cropland.

Some of the preferred crop varieties grown by farmers in the county are as follows: Corn—Reid Yellow Dent, Southwestern Yellow Dent, Johnson County White, Boone County White, and Iowa Silvermine; oats—Kanota and Red Rustproof (Texas Red); cotton—Arkansas Rowden 40, Early Triumph, Stoneville 2–B, Delta & Pine Land 11–A, and early strains of Acala; kafir—Sunrise, Dawn, Reed, and Blackhull; sorgo—Orange, Sumac, and Atlas; alfalfa—Common; potatoes—Bliss Triumph; wheat—Fulcaster, Kanred, Blackhull, Currell, Turkey, and Mediterranean; soybeans—Virginia, Tokyo, Laredo, and Dixie; and cowpeas—Whippoorwill and Clay. Several varieties of milo and feterita also are grown.

The soils of Tulsa County are grouped on the bases of soil characteristics, relief, and drainage conditions that influence their adaptation to the various crops, as follows: (1) Smooth-lying Prairie soils with moderately heavy textured subsoils; (2) soils with dense clay subsoils (Planosols) on smooth upland plains; (3) well-drained alluvial soils; (4) poorly drained alluvial soils; (5) forested upland soils with friable subsoils; (6) soils generally unsuited for cultivation; and (7) nonarable soils and miscellaneous land types.

In the following pages the soils of the county are described in detail, and their agricultural relationships are discussed; their location and distribution are shown on the accompanying soil map; and their acreage and proportionate extent are given in table 4.

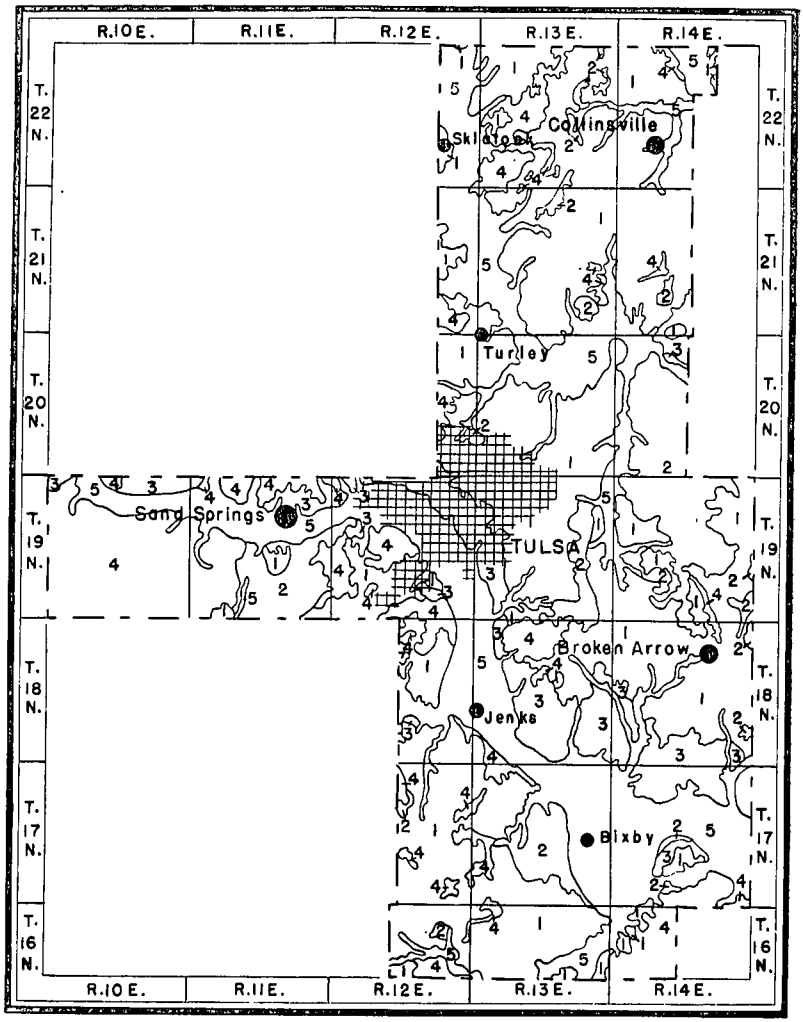


FIGURE 2.—General distribution of major soil areas in Tulsa County, Okla.: 1, Soils of the smooth prairie lands, mainly Bates and Parsons soils, developed from shales and sandstones; 2, soils of the smooth prairie lands, mainly Summit and Newtonia soils, developed chiefly from limestone (includes some stony soils); 3, soils of the smooth and rolling upland terraces, mainly Dougherty, Teller, and Stidham soils, developed from old alluvium; 4, thin and stony soils of the prairies and thin, stony, and steep broken lands of timbered areas, mostly nonarable; 5, alluvial soils of the flood plains of streams, mainly Verdigris, Yahola, Osage, Lonoke, Lightning, Brewer, and Miller soils.

TABLE 4.—*Acreage and proportionate extent of the soils mapped in Tulsa County, Okla.*

Soil type	Acres	Per-cent	Soil type	Acres	Per-cent
Bates very fine sandy loam	60, 224	16. 1	Lightning silty clay loam	6, 272	1. 7
Bates very fine sandy loam, deep phase	15, 104	4. 0	Lightning silty clay	1, 600	. 4
Bates fine sandy loam	11, 264	3. 0	Perry clay	896	. 2
Bates fine sandy loam, deep phase	960	. 3	Teller very fine sandy loam	9, 408	2. 5
Bates silt loam	2, 496	. 7	Dougherty very fine sandy loam	9, 216	2. 5
Fitzhugh very fine sandy loam	2, 304	. 6	Stidham very fine sandy loam	1, 728	. 5
Summit silty clay loam	25, 664	6. 8	Stidham fine sandy loam	2, 816	. 8
Summit clay	704	. 2	Stidham loamy fine sand	2, 368	. 6
Newtonia silty clay loam	3, 072	. 8	Hanceville fine sandy loam	3, 264	. 9
Newtonia fine sandy loam	448	. 1	Stidham fine sand	2, 880	. 8
Parsons silt loam	49, 088	13. 1	Talihina silty clay loam	2, 880	. 8
Parsons silt loam, deep phase	2, 496	. 7	Collinsville very fine sandy loam	10, 368	2. 8
Parsons silt loam, slope phase	3, 776	1. 0	Yahola loamy fine sand	3, 840	1. 0
Cherokee very fine sandy loam	320	. 1	Verdigris loamy fine sand	1, 408	. 4
Lonoke very fine sandy loam	5, 184	1. 4	Talihina stony clay loam	4, 224	1. 1
Brewer silty clay loam	2, 816	. 8	Denton stony clay loam	6, 336	1. 7
Brewer silty clay	1, 408	. 4	Collinsville stony fine sandy loam	9, 984	2. 7
Yahola very fine sandy loam	16, 128	4. 3	Crawford stony loam	3, 008	. 8
Yahola loamy very fine sand	1, 280	. 3	Hector stony fine sandy loam	9, 152	2. 4
Miller silty clay	4, 096	1. 1	Rough stony land (Hector soil material)	21, 696	5. 8
Miller loam	2, 688	. 7	Rough gullied land	13, 184	3. 5
Verdigris very fine sandy loam	11, 968	3. 2	Mine dumps	1, 344	. 3
Verdigris loam	11, 008	2. 9	Riverwash	3, 904	1. 0
Verdigris silty clay loam	4, 864	1. 3			
Osage silty clay loam	2, 112	. 6	Total	374, 400	-----
Osage silty clay	1, 152	. 3			

SMOOTH-LYING PRAIRIE SOILS WITH MODERATELY HEAVY TEXTURED SUBSOILS

The smooth-lying Prairie soils with moderately heavy textured subsoils include members of the Bates, Fitzhugh, Summit, and Newtonia series. The Bates soils have developed from fine-grained sandstone and shale parent materials. They have smooth undulating to gently rolling surfaces, brown surface soils, and deep or moderately deep crumbly subsoils. Both the Newtonia and the Summit soils are developed from limestone parent materials. The Newtonia soils are characterized by dull reddish-brown surface soils and red friable subsoils, and the Summit soils by very dark surface soils and olive-gray moderately heavy subsoils. Originally the soils in this group supported a cover of tall prairie grasses, but at present the acreage of unbroken hay and pasture land is small and widely scattered.

The soils of this group are favorable to the production of various crops, owing to their smooth surfaces, moderately high content of organic matter, and moderately friable subsoils, which allow free and unobstructed development of roots as well as free movement of underground moisture. About 75 percent of their total area is cropped. Special crops, such as tomatoes, melons, berries, and other truck crops, grow well on these soils. They are reported to respond to applications of manure or commercial fertilizer. Fruits are grown mostly in small orchards for home use, as other soils are better suited to growing fruits.

Approximately 35 percent of the cultivated soils in this group are cropped to corn, 25 percent to small grains, 10 percent to cotton, 6 percent to hay crops, 5 percent to sorghums and forage crops, and the rest to miscellaneous crops, orchards, and pasture.

Tests show that lime either is absent or is present in very small quantities to a depth of 4 to 5 feet in the Summit and Newtonia

soils, and that it is generally absent throughout the soil and parent materials in the Bates soils. Acidity in the Bates soils is not too great to prevent the growth of alfalfa without liming, although treatment with lime assures not only better stands and heavier yields but also longer life to the plants.

Inasmuch as most farmers raise some livestock for market, corn has always been an important crop on these soils, which are preferred as being better suited to corn than are the claypan soils of the Parsons series. The productivity of many of the older cultivated fields has been lowered by almost continuous cropping of corn without replenishing the depleted plant nutrients, especially organic matter and nitrogen, and by unchecked erosion, especially on the more sloping fields. The yearly average yield per acre, therefore, differs considerably from one year to another. Acre yields of corn ordinarily range from 18 to 40 bushels, wheat 8 to 20 bushels, oats 20 to 35 bushels, kafir 25 to 30 bushels, tame hay ¾ to 1 ton, wild prairie hay ½ to 1½ tons, cotton ⅛ to ⅓ bale, and alfalfa 2 to 4 tons, depending on the stand and season.

Bates very fine sandy loam.—The surface soil of Bates very fine sandy loam (pl 1, *A*) consists of an 8- to 14-inch layer of brown or dark-brown very fine sandy loam, which grades into slightly lighter colored and slightly heavier textured soil material—generally brown heavy very fine sandy loam. At a depth of 18 to 20 inches this grades into light-brown or brownish-yellow crumbly very fine sandy clay loam. The lower part of the subsoil, below a depth of about 24 inches, ordinarily is light-brown or brownish-yellow friable very fine sandy clay containing numerous soft sandstone fragments and more or less gray and rust-brown mottling. The underlying partly disintegrated sandstone and shale material occurs at a depth ranging from about 3 to 6 feet, thus allowing ample range for unobstructed root development for various field and orchard crops. In places closely associated with the Parsons soils, where the surface is smoother and less sloping, the friable crumbly subsoil material grades at a considerable depth into rather tough subsoil material somewhat like the corresponding layer of the Parsons soils.

The relief of this soil ranges from mildly undulating to sloping or gently rolling, as it occupies smooth hill crests and the gentle slopes. Surface drainage and underdrainage are good. Good water is obtained from wells ranging from 30 to 50 feet in depth, in the vicinity of most farm homes.

Agriculturally, this is the most important soil in the group, and it is the most extensive soil in the county. Probably about 75 percent of the land is cultivated, and the rest is utilized for wild hay and pasture; but practically all of this soil could be cultivated. Some areas have been encroached on by the gradual expansion of the city of Tulsa and several towns. The largest single body lies within and east of Tulsa, but the soil is widely distributed over the more level parts of the county.

Because of its sandy texture and loose consistence, this soil drains rapidly and warms quickly in the spring, allowing early cultivation and cropping. Early truck and garden crops, floral crops, berries, and orchard crops, such as peaches, pears, and apples, do well, owing to the permeability of the surface soil and subsoil and the consequent

good internal drainage. Average yearly crop yields are difficult to estimate because of their fluctuation from year to year, owing to climate, past treatment of the soil, and methods of land use. It is estimated that the average acre yield of the common field crops is as follows: Corn, 18 bushels; oats, 25 bushels; cotton, one-third bale; grain sorghums, 20 bushels; alfalfa, 2½ tons; and wheat, 13 bushels. With proper crop rotations, including the use of legumes (pl. 2, *A*) and commercial fertilizer, yields could probably be considerably increased.

In view of the high erodibility of this soil and its inability to withstand prolonged erosion, it is advisable to terrace most fields and employ cropping practices designed to minimize erosion; otherwise much of the land cannot be expected to produce crops profitably for any great length of time. With proper care and management, however, the soil will remain productive indefinitely.

Bates very fine sandy loam, deep phase.—This soil differs from typical Bates very fine sandy loam mainly in that the surface soil is thicker and in most places slightly darker and the parent material—shale or very fine grained sandstone—lies at a greater depth below the surface. Its inherent fertility is somewhat higher than that of the typical soil.

The 12-inch surface layer is dark-brown very fine sandy loam, grading into brown or brownish-yellow friable silty clay loam or fine sandy clay loam. This, in turn, grades into moderately crumbly brownish-yellow clay at a depth of 18 to 20 inches. Below a depth ranging from 30 to 40 inches the subsoil is brownish-yellow crumbly clay or fine sandy clay with considerable variation in mottlings of rust brown, gray, and yellow, the gray color becoming more pronounced with depth.

This soil has the same gently sloping surface, together with excellent surface drainage and underdrainage, as other Bates soils. Its occurrence adjacent to and at about the same level as the outer border of the high-terrace soils indicates that some of the surface soil may have been developed from thin ancient deposits of soil materials at the time the old alluvial terraces were laid down by the Arkansas River. Most areas of this soil are southeastward from Tulsa, but a few lie along the border of Mingo Creek Valley, much of which may have been covered with backwater at one time.

This soil is suited to and used for practically the same crops as those grown on the typical soil, although the average yields are somewhat higher. Yields of corn probably average about 22 bushels an acre, oats 26 bushels, wheat 14 bushels, and grain sorghums about 24 bushels. A larger proportion of this soil is planted to orchards than of other Bates soils. Truck crops are well suited, but moisture conditions are less dependable than on the well-drained bottom-land soils. About 85 percent of the land is in cultivation.

Bates fine sandy loam.—Bates fine sandy loam, as mapped in this county, consists of areas of fine sandy loam, including small areas of very fine sandy loam, and in a few places small areas of loamy fine sand or loamy very fine sand. The soil appears lighter colored in plowed fields, is slightly more rolling, and lies higher than Bates very fine sandy loam. The interbedded sandstone and shale parent material also generally lies nearer the surface than it does in Bates very fine sandy loam. Compared with that soil, Bates fine sandy loam is

more susceptible to drifting in heavy winds, because of the greater content of sand and the apparent lower content of organic matter. Like that soil, it is highly erodible, and careful management is necessary to maintain its fertility.

The surface soil, to an average depth of 10 inches, is brown rather loose fine sandy loam. This material grades into lighter brown fine sandy loam or loam, which, at a depth of about 16 to 18 inches, is underlain by brownish-yellow mottled friable clay loam. In most places the soil material grades into crumbly shale or shaly sandstone at a depth ranging from 25 to 40 inches. In old cultivated fields some shaly fragments are noticeable on the surface in places. The surface soil and subsoil are slightly or moderately acid, but the lower part of the subsoil and the substratum are almost neutral.

Although this soil is much less extensive than Bates very fine sandy loam, it occupies a fairly large total area. The largest bodies are a few miles northeast of Owasso. Probably about 80 percent of the land is cultivated, and the rest is used mainly for wild hay and pasture for livestock.

All the crops common to this county are grown with fair success on this soil. The general deficiency in organic matter indicates a need for a more systematic crop rotation including legumes, in order to maintain the productivity of the soil. The use of barnyard manure is beneficial, especially for corn. Such crops as sweetpotatoes, melons, peanuts, and many other truck crops do well if properly fertilized. Alfalfa does not grow very well, owing to the inadequate supply of underground moisture, drought in late summer, and deficiency in lime. Ordinarily yields of crops are slightly lower than on Bates very fine sandy loam.

Bates fine sandy loam, deep phase.—Bates fine sandy loam, deep phase, occurs along the outer border of the high old stream terraces. It occupies only a few small areas, chiefly about 3 miles south and southwest of Broken Arrow. Soil of this phase differs from Bates very fine sandy loam, deep phase, mainly in having a surface covering of fine sandy loam. A few small areas of loamy fine sand are included in mapping. This cover of sandy material was probably laid down by very high overflow waters of the Arkansas River in the past. In places, this soil closely resembles Stidham fine sandy loam.

The surface soil consists of a 10- to 14-inch layer of brown fine sandy loam, underlain by a slightly lighter colored and heavier textured soil material. At a depth of 18 to 20 inches, this grades into brownish-yellow friable fine sandy clay, the content of fine sand decreasing with depth. The lower part of the subsoil, below a depth ranging from 24 to 30 inches, is friable fine sandy clay or very fine sandy clay, with some mottling of rust brown, reddish brown, and gray and some very dark stains. Small rounded dark pellets, similar to those of the corresponding layer of the typical soil, are present. Ordinarily thin-bedded fine-grained sandstone and shale material, like that underlying the other Bates soils, lies from 4 to 6 feet below the surface.

The relief is undulating, and both surface drainage and underdrainage are good. Practically all of the land is cultivated, and the crops grown and their yields are about the same as those on the typical soils.

Bates silt loam.—Bates silt loam, an inextensive soil, occurs mainly in the northern part of the county southwest of Collinsville. The

divides occupied by this soil are slightly broader and smoother than those occupied by other Bates soils. The surface soil is slightly heavier textured, and the subsoil, as a rule, is less friable, compared with the corresponding layers of typical Bates very fine sandy loam. The subsoil approaches the tough subsoils underlying the Parsons soils.

The surface soil is about 10 inches thick and consists of brown heavy silt loam or loam, underlain by brownish-yellow crumbly clay. Below a depth ranging from 18 to 24 inches, this grades into brownish-yellow crumbly slightly mottled silty clay. The texture becomes heavier and the mottlings of gray and yellow become greater with depth, and below a depth of 40 inches small red spots and semihard pellets or concretions occur. Shale and sandstone are present at a depth of several feet.

Surface drainage is good, and internal drainage is slow but adequate for crops. This soil is used mainly for the production of oats, corn, cotton, wheat, and prairie hay, and about 75 or 80 percent of it is cultivated. Crop yields are about the same as on Bates very fine sandy loam. Probably a slightly larger acreage is cropped to small grains and sorghums and a smaller acreage is planted to orchards than of Bates very fine sandy loam.

Fitzhugh very fine sandy loam.—The surface soil of Fitzhugh very fine sandy loam is dark-brown or dark grayish-brown very fine sandy loam about 8 inches thick. In places the soil in this layer has a red tinge, and all the older cultivated fields show a red tint. The upper part of the subsoil is dull reddish-brown loam or very fine sandy loam that grades, at a depth of about 18 to 22 inches, into brownish-red friable fine sandy clay. This merges with yellowish-red somewhat mottled clay that in places is splotched with shades of red, yellow, and gray. Fragmentary sandstone and shale are noticeable at a depth of 4 to 6 feet.

About 90 percent of this soil is cultivated. The main areas are from 2 to 3 miles southwest and northwest of Jenks, and a fair-sized area is south of Sand Springs. The surface is smoothly undulating. Because of the excellent surface and internal drainage, deep surface soil, and friable subsoil, this soil is adapted to a wide range of crops, the more important of which are corn, oats, cotton, and sorghums. The soil also is well suited to peaches, apples, pears, grapes, berries, and various truck crops and vegetables. Average acre yields are about 20 bushels of corn, 26 bushels of oats, 14 bushels of wheat, 22 bushels of grain sorghums, and one-third bale of cotton.

Summit silty clay loam.—Summit silty clay loam (pl. 1, *B*), to an average depth of 12 inches, is very dark grayish-brown silty clay loam. This material grades into dark grayish-brown or grayish-brown silty clay. This, in turn, grades, at a depth ranging from 18 to 24 inches, into olive-gray clay that is very slightly to distinctly mottled with gray and yellow. In most places a few lime concretions occur in the lower part of the subsoil at a depth of 3½ to 5 feet. Limestone, in partly disintegrated form, lies below a depth of 4 feet, but in places near the boundary of areas of Denton stony clay loam it lies only 20 to 26 inches below the surface. Only scattered remnants of limestone underlie the soil in some areas, such as those south of Bixby, and in many places limestone apparently is entirely lacking.

Because of its smooth surface and ability to absorb and hold water after spring rains, this soil does not dry so readily as the Bates soils, and the seeding of cotton or corn may be delayed for some time in the spring, with a subsequent delay in the date of maturity. Although surface drainage is good, underdrainage is only fair because of the generally heavy texture of the subsoil.

In the vicinity of Alsuma on a flat to undulating area of about 4 square miles, this soil is somewhat lighter colored in both surface soil and subsoil than the normal soil and somewhat resembles Parsons silt loam, with which it is associated; but, on the whole, it has characteristics and land-use relationships similar to those of typical Summit silty clay loam.

A few scattered areas of a shallow phase of this soil, owing to their very small extent, are included on the map with this soil. This inclusion has thin soil layers, owing to erosion, and is not highly productive.

In places on small spots of Summit silty clay loam a saline condition is indicated by a light-colored thin surface soil over a dense brown clay of claypan character, and this, below a depth of 20 inches, grades into yellowish-brown tough hard clay containing soft white particles of saline material. On drying thoroughly, both the surface soil and the subsoil become very hard and tight, and very little vegetation will grow. These spots are about 10 yards in diameter and from 20 to 30 yards apart, although in places they are so close together that they form almost continuous strips. It is reported that the physical condition of the soil in these spots is improved by working into it as much organic matter, such as barnyard manure or rotted straw, as practicable.

Summit silty clay loam is a fairly extensive soil. The larger areas are in the east-central part of the county, and a large area is in the southern part west of Bixby. Approximately 75 percent of the soil is cultivated, and the unbroken land is used mainly for prairie hay and pasture. Coarse bluestem grasses produce about 1 ton of excellent hay to the acre. Corn, oats, cotton, grain sorghums, and wheat are the chief crops. Although most of the lime has been leached from the surface soil and subsoil layers, the soil is only slightly acid, not sufficiently so to prevent the successful growth of alfalfa. Without liming, alfalfa succeeds better on the Summit soils than on the Bates soils, but liming is helpful in order to obtain best results. Inoculation of the seed also is advisable. Of the small grains, oats are probably better suited than wheat. This is a very good soil for the production of cotton. Orchards do fairly well in the best drained situations, but as yet there apparently are no large commercial orchards on this land.

Corn yields an average of about 20 bushels an acre, wheat 12 bushels, oats 25 bushels, grain sorghums 24 bushels, and cotton one-third bale. Some alfalfa is grown, and in good seasons it yields from 2 to 3 tons of hay an acre from several cuttings. It grows well, but the hot summer weather reduces the yield in some years. Some vegetables are grown successfully for home use.

Summit clay.—Summit clay occurs only in a few small areas. The soil is known locally as black gumbo land. The dark grayish-brown or black silty clay or clay surface soil is about 12 inches thick.

The subsoil consists of olive-gray clay similar to the subsoil of Summit silty clay loam. In a few places adjoining small drainageways, limestone is reached at a depth of 2 to 3 feet.

This soil is difficult to cultivate because of its heavy texture, but under optimum moisture conditions it breaks and crumbles easily. Ordinarily it occurs on lower slopes where it receives considerable run-off from higher ground. In such situations wet seasons tend to delay tillage operations for longer periods than on the lighter textured soils. Corn or other crops may be stunted and the leaves turn pale green or greenish yellow, owing to surplus moisture in the soil. If the season is not abnormally wet, corn, oats, sorghums, and cotton produce good yields. Unless good surface run-off is natural or provided, alfalfa is a very uncertain crop. In general, however, Summit clay is not so desirable for cultivated crops as is Summit silty clay loam. Approximately 80 percent of the land is cultivated, and the rest is used for grazing or growing prairie hay.

Newtonia silty clay loam.—Newtonia silty clay loam is locally known as red limestone land. It is developed mainly in the east-central part of the county and is closely associated with Summit silty clay loam. The silty clay loam surface soil in the virgin prairie is dark brown to dull reddish brown, but in cultivated fields it appears red or reddish brown. It is underlain, at a depth of 8 to 10 inches, by heavy reddish-brown silty clay loam, which, at a depth of 18 to 20 inches, grades into uniform reddish-brown crumbly clay or silty clay. This material continues to a depth ranging from 4 to 6 feet. Narrow areas of this soil that border Crawford stony loam are underlain by limestone at a depth of about 2 feet. The structure is loose and granular, and an excellent tilth is easily maintained under cultivation. The surface soil and the upper part of the subsoil are slightly acid, but the lower part of the subsoil is either neutral or calcareous.

Most areas of this soil occupy smooth ridge crests and gentle slopes, which assure good surface drainage. As yet, the productiveness of this soil has not greatly declined from the effects of erosion, but much of the surface soil has been removed on the older more sloping fields. The soil in such fields is slightly heavier textured and redder than the typical soil. Proper terracing and contour cultivation would greatly retard erosion on this land. About 90 percent or more of the soil is cultivated, and the rest is used as hay meadow and pasture.

All field crops common to this county succeed, but corn, small grains, sorghums, and cotton are more commonly grown. Alfalfa can be successfully grown, but stands are more certain and longer lived if the soil is well limed and the seed inoculated. Without the use of fertilizers, average acre yields are about 20 bushels of corn, 25 bushels of oats, 22 bushels of grain sorghums, 15 bushels of wheat, 2½ tons of alfalfa, and one-third bale of cotton. If proper fertilizer is applied, average yields would probably be considerably higher. Because of the permeable crumbly subsoil, such fruits as peaches, pears, plums, cherries, apples, and grapes are well suited. Potatoes and truck crops also yield well, especially when the soil is well fertilized.

Newtonia fine sandy loam.—Newtonia fine sandy loam has a very small total area. The main bodies are southwest and south of Sand

Springs. This soil is essentially like Newtonia silty clay loam in color and texture of the subsoil and in its origin from limestone parent material. Apparently the upper part of the soil has been modified by a thin covering of Hanceville fine sandy loam, either developed in place or eroded from higher areas of Hanceville soils. In a few places the surface soil ranges from fine sandy loam to very fine sandy loam, but generally the reddish-brown fine sandy loam surface soil is underlain at a depth ranging from 12 to 18 inches by reddish-brown moderately friable silty clay loam or silty clay, characteristic of the Newtonia soils. The lower subsoil layer consists of reddish-brown crumbly clay like that underlying Newtonia silty clay loam. In a few places bordering other soils, this soil is underlain by limestone rock at a depth of 3 to 4 feet.

About 90 percent of the land is cultivated, for the most part to corn. Average yields of the general farm crops are probably about the same as those on Newtonia silty clay loam. This is a good soil for orchard fruits, berries, vegetables, and corn. The land is easily tilled and responds well to applications of fertilizers.

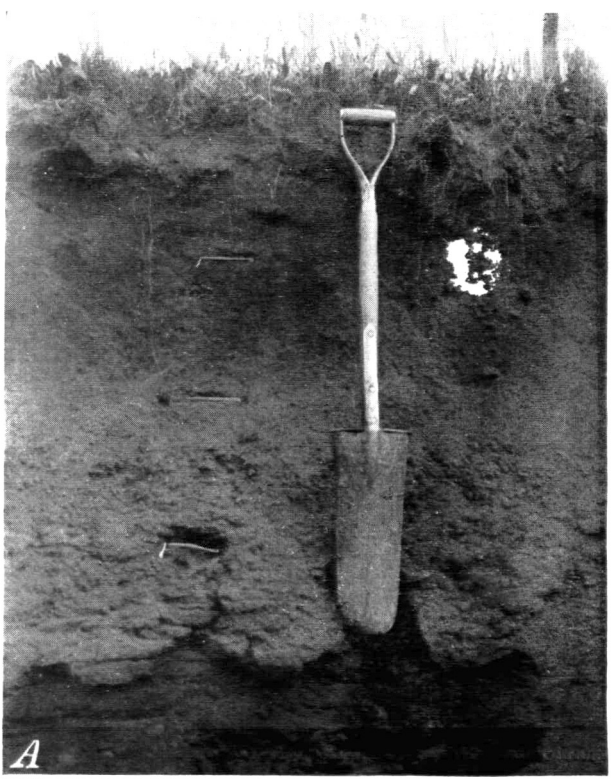
SOILS WITH DENSE CLAY SUBSOILS (PLANOSOLS) ON SMOOTH UPLAND PLAINS

Soils with dense clay subsoils (Planosols) occurring on smooth upland plains are grayish brown. They include members of the Parsons and Cherokee series. Underdrainage is very slow, and the tough subsoils do not favor the growth of deep-rooted plants. The reaction is medium acid, and the supply of organic matter is low. These soils have a smooth and slightly undulating surface. With excessive rainfall the growth of many crops is retarded, and in very dry seasons the surface soil and the subsoil pack densely, shrink, crack, and become droughty. Shallow-rooted plants, such as grasses, small grains, and grain sorghums, do better than deep-rooted plants, such as corn and alfalfa. These soils are not well suited to fruits and only moderately well suited to vegetables. About 70 percent of the land is cultivated.

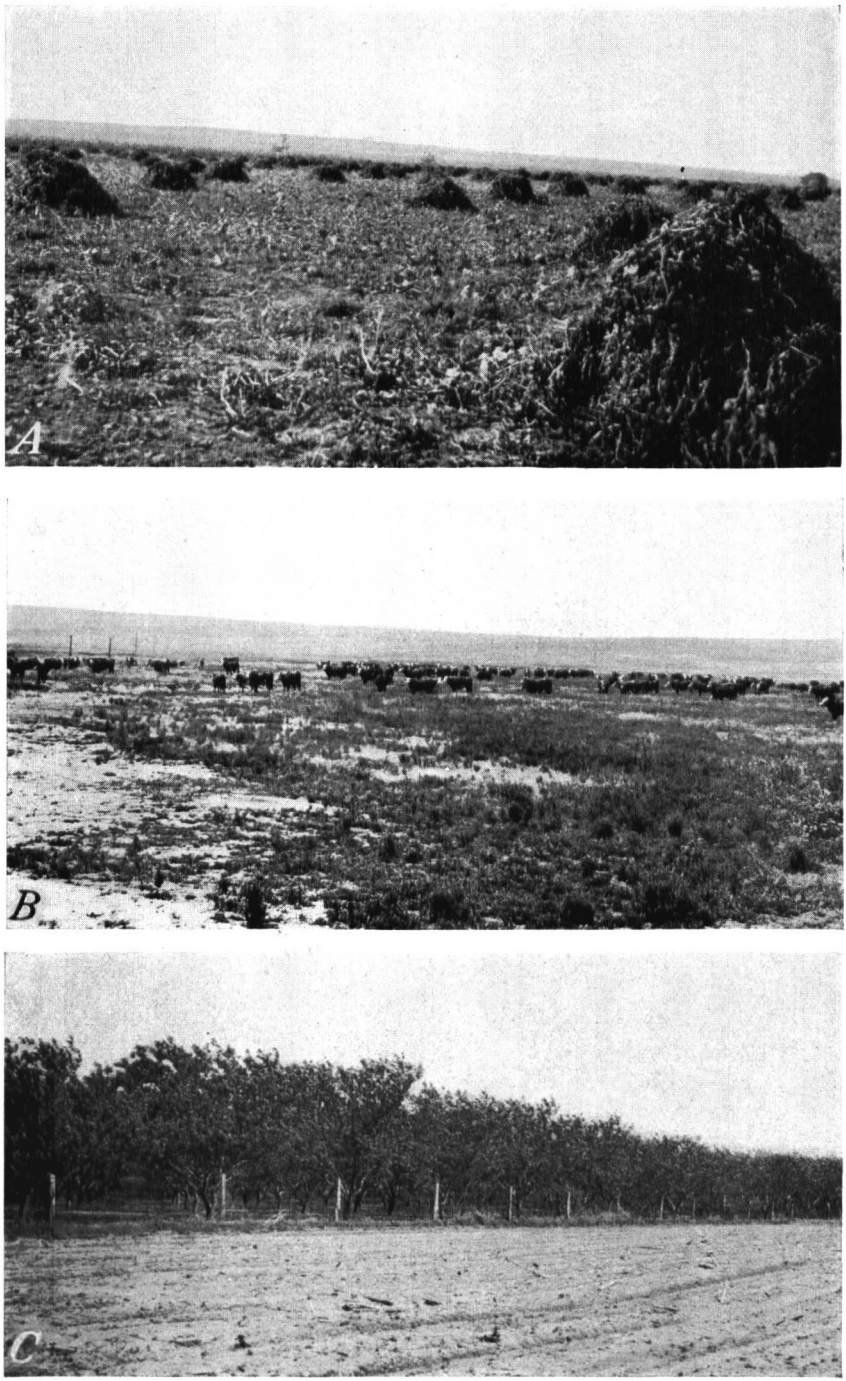
Parsons silt loam.—The 10-inch surface layer of Parsons silt loam is grayish-brown heavy silt loam containing considerable very fine sand. On drying it appears dark gray. It is underlain by a thin layer of lighter gray silt loam of about the same texture. At a depth of 12 to 16 inches, and slightly deeper in places, the gray layer is abruptly underlain by brown or grayish-brown tough dense clay that forms a claypan. This has, in places, slight yellow and gray mottlings below a depth of 20 to 24 inches. The dense clay continues downward several feet, where it rests on partly disintegrated shale, the formation that gives rise to the soil parent material. Both surface soil and subsoil are moderately acid in reaction.

Parsons silt loam is extensive and occupies many small and large areas throughout the prairie areas. In the southwestern part of the county large bodies extend from Glenpool southeastward for several miles, and in the eastern part more or less disconnected areas reach northward from a few miles west of Broken Arrow through Owasso to the northern county line near Collinsville.

The surface of this soil is gently undulating or nearly flat. Surface drainage is very good, but underdrainage is very deficient. Owing to its very moist condition in winter and spring and its dry condition



A, Profile of Bates very fine sandy loam; *B*, profile of Summit silty clay loa



A, Soybeans for hay on a sloping field of Bates very fine sandy loam; *B*, cattle grazing on Parsons silt loam in the foreground and Talihina stony clay loam in the background; *C*, an 80-acre Elberta peach orchard on Stidham fine sandy loam.

in summer, the soil is better suited to small grains than to most of the other crops grown. Probably a larger proportion of oats is grown on this soil than on most of the other soils, but a considerable acreage is devoted to corn, grain sorghums, and cotton. Such crops as oats, wheat, and barley have shallow rooting systems and yield better on this soil than some other crops, as they take advantage of the soil moisture stored in the winter and mature before the dry season.

Cowpeas, soybeans, and sweetclover are said to grow well on this soil. Grain sorghums do better than corn, as they withstand hot, dry seasons better. Cotton does fairly well but not so well as on the Prairie soils that do not have claypan subsoils. It is reported that phosphatic fertilizers applied to this soil give good results with small grains. Corn, fruits, vegetables, and alfalfa are grown to some extent but are not highly successful. Oats yield from 18 to 35 bushels an acre, averaging about 22 bushels; wheat, 10 to 20 bushels, averaging about 12 bushels; corn, 10 to 25 bushels, averaging about 15 bushels; and grain sorghums, 25 to 30 bushels, averaging about 18 bushels. Cotton produces an average of about 100 pounds an acre. Approximately 70 percent of this soil is in cultivation, and the rest is utilized for pasturage (pl. 2, *B*) and hay. Oats, cotton, and corn are the chief crops grown. About the same acreage is in cotton as in oats, and a smaller acreage of grain sorghums is grown.

Parsons silt loam, deep phase.—The surface soil of Parsons silt loam, deep phase, is dark grayish-brown silt loam about 15 inches thick, which grades into gray silt loam or heavy very fine sandy loam. At a depth of about 26 inches this rests on tough yellow and gray mottled clay. This soil is very similar to typical Parsons silt loam except that the dense claypan lies at a greater depth beneath the surface.

Parsons silt loam, deep phase, occupies only a few small areas in the southeastern part of the county within a few miles west and south of Broken Arrow. It is associated with areas of the typical soil and other Prairie soils.

The surface is gently undulating. Surface drainage is adequate, but under-drainage is very slow. In many places the surface slope is slightly more pronounced than that of typical Parsons silt loam, and erosion is severe on fields planted to row crops that require clean tillage. Broad-base terraces and contour cultivation are necessary on such fields if the land is expected to produce satisfactory yields indefinitely.

About 80 percent of this soil is in cultivation, and practically the same crops are grown as on typical Parsons silt loam. Owing to the thicker surface soil, this soil is somewhat more productive and returns slightly higher yields, especially of cotton and corn, than typical Parsons silt loam.

Parsons silt loam, slope phase.—The 8- to 12-inch surface soil of Parsons silt loam, slope phase, is dark-gray silt loam. The material in the lower part of the layer is slightly lighter colored than that above. This layer rests on a dense tough claypan that is mottled yellow and brown with some gray streaks and splotches and, in places, small red specks. When exposed, the clay dries to a very hard, tight mass, which is very intractable and difficult to cultivate. The subsoil contains a few black concretions and some white hard concretions of lime.

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This soil occurs on slopes of high old terrace benches in places, and in such places the derivation of the parent materials is uncertain, as no shale beds are noted, although they may be too deeply weathered to be reached in the usual course of soil examination.

Parsons silt loam, slope phase, has only a small total area and occurs only in the southeastern part of the county, largely within a few miles of Broken Arrow, where it occupies narrow strips on slopes bordering higher lying areas of soils of the Parsons, Bates, and other series.

The slope ranges from 3 to 6 percent and is sufficient to allow rapid erosion where the soil is not protected. Erosion is the most serious problem in cropping this soil, as it can lose only a small quantity of the surface soil and continue to be cropped successfully. The chief crops grown are oats, sorghums, corn, and cotton. Estimated average acre yields are 15 bushels of corn, 20 bushels of oats, 18 bushels of grain sorghums, 11 bushels of wheat, and one-fourth bale of cotton.

Cherokee very fine sandy loam.—The surface soil of Cherokee very fine sandy loam, to a depth of 12 to 14 inches, is dark-gray very fine sandy loam containing a large quantity of silt. On drying it becomes light gray on the surface. The soil is rather low in organic matter and frequently bakes to a hard mass, especially in hot dry weather. The lower part of the surface soil, a layer about 4 inches thick, is light-gray material—somewhat lighter colored than the material above. This layer, at a depth of about 16 to 18 inches, is abruptly underlain by dense tough grayish-brown clay, which is a claypan and contains some yellow spots and small silt pockets throughout. The reaction of the surface soil and the subsoil is medium to strongly acid in places.

This soil occupies a few very small areas in the southeastern part of the county, from 3 to 4 miles northeast and northwest of Broken Arrow. The surface is nearly flat. Surface drainage is very slow, underdrainage is inadequate, and ordinarily the soil remains wet for a considerable part of the winter.

Cherokee very fine sandy loam is a Prairie soil having much the same native vegetative cover as Parsons silt loam, with which it is associated. About the same crops are grown on both soils, but average acre yields are somewhat lower on the Cherokee soil. It is an excellent soil for hay from native grasses.

WELL-DRAINED ALLUVIAL SOILS

Well-drained alluvial soils occupy the well-drained first bottoms of the Arkansas River Valley and the small streams. They include members of the Lonoke, Brewer, Yahola, Miller, Verdigris, and Osage series.

In general, many of these soils have a wide range of crop adaptability, and, because they contain comparatively large quantities of essential available plant nutrients and have very favorable physical soil characteristics, they are inherently highly fertile. Overflows occur occasionally but are not so frequent as to impair the cropping value of these soils for the entire season. The subsoils are loose and crumbly, and even the heavy-textured surface soils readily crumble when worked after drying sufficiently. Some are calcareous, and

others are acid in reaction. Owing to the permeable subsoils and substrata, plant roots have an exceptionally wide feeding range, and, during periods of drought, crop yields are higher than those produced on the smooth-lying Prairie soils of the first and second groups. With proper care and management, the productivity of these soils can be maintained indefinitely. About 95 percent of their total area is cultivated.

The Lonoke soils occupy slightly higher to considerably higher levels than the Brewer, Miller, or Yahola soils. They have dark grayish-brown surface soils with grayish-brown friable to moderately heavy subsoils. The Brewer soils are dark-colored heavy-textured soils associated with the Lonoke. They occupy slightly lower areas and are generally less well drained than the Lonoke. The Yahola soils have light-brown or reddish-brown fine sandy surface soils with variable light-colored and light-textured subsoils, whereas the Miller soils have dull reddish-brown medium-textured surface soils with reddish-brown or dull reddish-brown heavy subsoils. The soils of both series are calcareous. The Verdigris soils are characterized by brown medium- to light-textured surface soils with friable light-brown subsoils. The Osage soils have dark grayish-brown or grayish-brown moderately heavy textured surface soils and moderately heavy textured gray or olive-gray subsoils.

The Yahola, Miller, Brewer, and Lonoke soils consist largely of soil materials originating in the "Red Beds" of western Oklahoma. The Verdigris soils consist largely of materials washed and transported from the Bates, Parsons, and Newtonia soils, either of this county or of northern Oklahoma. The Osage soils are derived from alluvial soil materials, chiefly from dark Prairie soils, largely of the Summit series.

Lonoke very fine sandy loam.—Lonoke very fine sandy loam consists of uniform brown or very dark brown very fine sandy loam, grading, at a depth of 16 to 20 inches, into lighter brown heavy very fine sandy loam or light-textured sandy clay loam. In places below a depth ranging from 30 to 40 inches are slight mottlings of yellowish brown and gray. The movement of internal moisture is fairly free, owing to the permeable subsoil.

This soil occurs on the oldest and higher lying smooth flat benches of the Arkansas River flood plain. It is reported that complete overflow of this soil has not occurred since it has been placed in cultivation. Both surface and internal drainage are excellent. This soil occupies a few fairly large bodies, such as those lying a few miles south of Tulsa and those northeast of Bixby.

The chief crops grown are corn, cotton, and alfalfa, but all crops adapted to the climatic environment do well and produce excellent yields. In places considerable acreages are used for truck crops, fruits, and berries, and some vineyards and orchards are on this soil. It is also a good soil for commercial nurseries. Yields of corn range from 18 to 60 bushels an acre, probably averaging about 30 bushels; cotton, one-fourth to three-fourths bale, with an average of nearly one-half bale; and alfalfa, 3 to 5 tons a season from four or five cuttings, with probably a seasonal average of 4 tons. It is estimated that the average acre yield for grain sorghums is about 28 bushels, oats 28 bushels, and wheat 15 bushels. Practically all of this soil

is under cultivation. Originally it supported a forest cover of a number of species of trees, mainly oak, elm, hickory, and ash, common to other well-drained bottom-land soils.

Brewer silty clay loam.—Brewer silty clay loam is closely associated with Lonoke very fine sandy loam, but its total acreage is much smaller. The elevation of most areas of the Brewer soil is slightly lower than that of adjoining areas of the Lonoke soil.

Brewer silty clay loam is characterized by an 8- to 12-inch dark-brown or dark grayish-brown silty clay loam surface layer merging with lighter brown silty clay loam, which, at a depth ranging from 16 to 30 inches, grades into grayish-brown or dark-gray silty clay containing yellow, gray, and rust-brown mottlings.

A number of areas too small to show individually on a small-scale map are included with this soil. The soils in these areas have a dark-brown loam surface soil and a similar, slightly heavier, subsoil. In places, the surface of this included soil is slightly depressed, producing rather slow surface drainage, and the subsoil is sufficiently heavy to retard underdrainage for short periods.

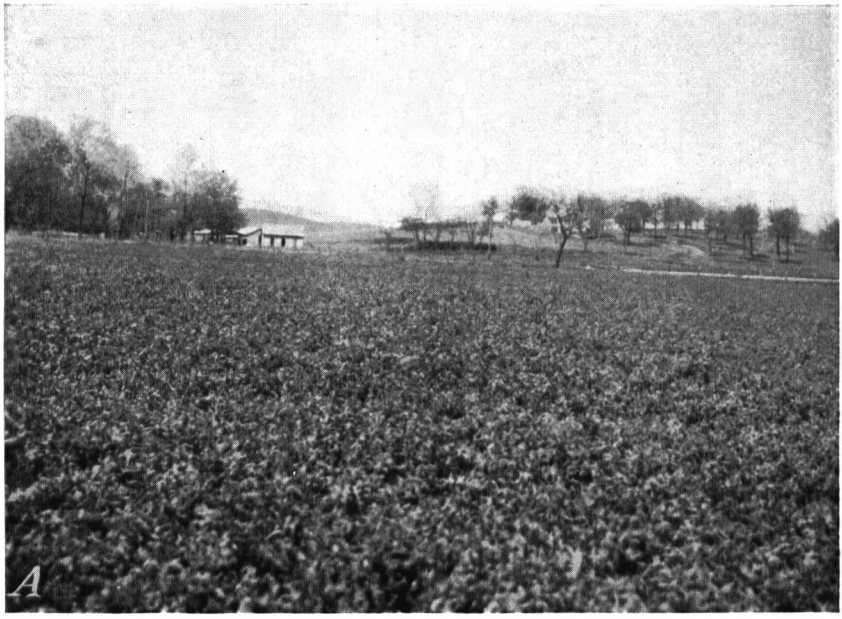
Most of the areas of typical Brewer silty clay loam have sufficient surface drainage and underdrainage to allow successful cultivation of crops. Several narrow strips of this soil are along the slightly higher benches of the Arkansas River flood plain. One of the larger areas is southeast of Bixby and one is 2 miles northeast of Jenks.

About 95 percent of the land is cultivated. Corn, cotton, oats, and various other crops grow well, and many truck crops would be successful. Native pecan trees are scattered over a number of places. Many of these were left when the land was cleared and do not interfere with cultivation. Several paper-shelled pecan groves have been set out. Crop yields compare favorably with those on Lonoke very fine sandy loam. Alfalfa does well on the better drained areas and yields about 4 tons an acre in a season.

Brewer silty clay.—Brewer silty clay is closely associated with Brewer silty clay loam, but it occupies slightly lower positions. Most areas lie nearest the bluff side of the bottom lands and have very smooth surfaces which do not allow the escape of surface run-off so readily as do the associated soils. The surface soil is dark grayish-brown or nearly black silty clay, which, below a depth of 40 inches, has some fine mottling of yellowish brown and light gray. In places the lower part of the subsoil is slightly calcareous.

This soil is inextensive. About 80 percent is cultivated; the rest is used for pasture and to some extent for pecan trees. Small areas are 3 miles north of Bixby and between this point and Tulsa. The native trees are mainly pecan, ash, elm, and oak.

This soil is especially in need of ample surface ditches in order to drain off all surplus rainfall. Difficulty of tillage is another factor that affects the soil unfavorably. Where adequate drainage through surface ditches has been provided, alfalfa is the chief crop, but even under such conditions some new stands of alfalfa have been drowned out. This soil is naturally productive but is better suited to alfalfa, corn, and cotton than to most truck and orchard crops. Crop yields on the better drained areas average about 28 bushels of corn, 30 bushels of oats, and one-third bale of cotton an acre. Ordinarily alfalfa returns equal yields and in places the yields exceed those on



A, Alfalfa growing on Yahola very fine sandy loam in the foreground and rolling forested Teller very fine sandy loam in the background; *B*, orchard on Yahola very fine sandy loam, containing native pecan trees, which grow throughout the Arkansas River Valley.

Brewer silty clay loam. Owing to the heavy texture of the surface soil, this soil is slow to dry out after rains, difficult to cultivate, and at all times favorable to a fast and rank growth of weeds. If plowed too wet, the soil is likely to puddle or bake; and only under very favorable moisture conditions does it cultivate and crumble easily.

Yahola very fine sandy loam.—In Tulsa County, Yahola very fine sandy loam is the most extensive soil in the Arkansas River bottoms. Inundation by overflow waters occurs once in about 10 to 15 years. This soil does not contain so much organic matter as the Lonoke and Brewer soils, which lie on low benches from 4 to 8 feet higher than those occupied by the Yahola soil.

The surface ranges from smooth to irregular. Near the river the land in most places is slightly hummocky and consists of a succession of slightly elevated broad wavelike swells with intervening slightly depressed areas. Owing to the generally porous condition of the surface soil and the subsoil, both surface drainage and underdrainage are good.

The surface soil of Yahola very fine sandy loam consists of brown, dark-brown, or reddish-brown very fine sandy loam, ranging from 10 to 15 inches in thickness, which is calcareous and contains little organic matter. It grades into light-brown or light reddish-brown calcareous loamy very fine sand, which contains layers of heavier textured soil materials and, below a depth of 3 feet, in most places gives way to very loose fine sand. The smoother areas some distance from the river have a more uniform subsoil than other areas, and generally have a higher clay content in the gradational layers. When viewed from a distance, the cultivated fields have a slightly red tint.

The mapped areas include some small strips or rises in which the soil texture ranges from very fine sandy loam to loamy very fine sand. The soil in such strips is slightly lighter brown and is more susceptible to drifting than the typical soil. Such areas tend to lower slightly the agricultural value of the land.

A few areas now occupied by oil refineries and tank fields have many artificial surface variations, such as pondlike embankments around the numerous large storage tanks. Nearly all of the areas, owing to excellent internal drainage, are sufficiently well drained to allow cropping, even in low situations.

Notwithstanding the many slight surface variations and underground textural gradations, this soil is uniformly productive. Corn, cotton, alfalfa (pl. 3, *A*), and many truck crops are grown. Corn yields from 20 to 40 bushels an acre, cotton one-eighth to one-half bale, and alfalfa 3 to 5 tons from four and sometimes five cuttings a season. Average acre yields are probably about 28 bushels of corn, 23 bushels of oats, 10 bushels of wheat, two-fifths bale of cotton, and 3½ tons of alfalfa. Potatoes and sweetpotatoes, melons, tomatoes, and other truck crops do well. Excellent orchards of native pecan trees (pl. 3, *B*) are maintained. It is reported that applications of stable manure increase yields of most crops.

As this soil is generally low in organic matter, some farmers grow legumes, such as cowpeas, soybeans, alfalfa, or sweetclover, and turn under a green-manure crop on part of the cropped land each season, or as often as convenient under the particular cropping system. This land is very responsive to good treatment, and liberal quantities of

manure, commercial fertilizer, or green-manure crops will add greatly to the yields of most crops. Practically all of the land, other than that covered by subdivisions, oil refineries, and other manufacturing plants near the cities and towns is cultivated.

Yahola loamy very fine sand.—The main areas of this soil, which are small, are a few miles south of Tulsa and north of Bixby on the Arkansas River flood plain. This soil possesses characteristics intermediate between those of Yahola very fine sandy loam and those of Lonoke very fine sandy loam. The surface soil and the subsoil are slightly lighter in color and in texture than the corresponding layers of Lonoke fine sandy loam, but this soil occupies the same bench as the Lonoke soil, although most of it lies at slightly lower levels than that soil. The surface configuration in most places consists of rather long hummocky ridges, or rises, with intervening depressed swalelike areas; in other places faint remnants of low flat mounds are apparent and impart a somewhat spotted appearance. Some areas are fairly smooth, but the surface is not so consistently smooth as that of Lonoke very fine sandy loam.

The surface soil is brown or reddish-brown loamy very fine sand or very fine sandy loam. This grades, at a depth of 10 to 15 inches, into lighter reddish brown very fine sandy loam or loamy very fine sand, which, in turn, grades at a depth ranging from 20 to 30 inches, into yellowish-brown or reddish-brown friable silty clay loam or very fine sandy loam. The texture and color of the subsoil are variable, corresponding to those features of the subsoil of Yahola very fine sandy loam. In a few slightly higher situations where this soil joins Lonoke very fine sandy loam, the surface soil, to a depth of 8 to 10 inches, is light-brown or slightly reddish brown loamy very fine sand. It is underlain by light-brown or yellowish-brown loamy very fine sand. This overlies a buried soil that is typical Lonoke very fine sandy loam. The overlying deposit ranges from 20 to 40 inches in thickness on the outer benchlike extremity and gradually thins out near the river. In places very small areas of Lonoke very fine sandy loam are included in mapping.

Practically all of this soil is cultivated, and corn, cotton, oats, and various truck crops are most commonly grown. The average acre yields are about the same as those on Yahola very fine sandy loam. This soil is well suited to many kinds of berries, orchard fruits, and vegetables, which are grown largely for the local market. Although the surface soil and the subsoil are not everywhere calcareous, according to field test, the soil is not acid but is about neutral in reaction.

Miller silty clay.—Miller silty clay occurs in small widely scattered areas throughout the Arkansas River flood plain. Most of the areas occur in slightly depressed situations and in old stream channels where the backwater of overflows has deposited, and still deposits, soil materials. Surface drainage of most of the land is adequate, as some areas have been ditched, but others are still inadequately drained.

Miller silty clay has a dark brownish-red or dull-red calcareous clay surface soil, about 10 inches thick. It is underlain by brownish-red calcareous clay or silty clay, extending to a depth of 3 feet or more. In places the lower part of the subsoil, below a depth of 26 to 30 inches, includes layers of material varying in texture, color, and

thickness. Small areas of Yahola silty clay, too small to be shown on a small-scale map, are included with this soil. The Yahola soil is very similar to Miller silty clay in the surface soil but has sandy layers in the subsoil that vary in texture and thickness.

Approximately 70 percent of Miller silty clay is cultivated; the rest is in native forest, mainly pecan, hickory, elm, ash, willow, sycamore, black oak, hackberry, honeylocust, walnut, and other trees. Corn, cotton, and alfalfa are the chief crops grown. Corn yields are reported to range from 20 to 40 bushels an acre, cotton one-eighth to five-eighths bale, and alfalfa 3 to 5 tons. Estimated average yearly acre yields are 30 bushels of corn, 15 bushels of wheat, 28 bushels of grain sorghums, 4 tons of alfalfa, and one-half bale of cotton. Some areas in cultivation support scattered large native pecan trees that produce good yields of nuts. Some orchards of improved pecans have been set on this soil, and for the most part the trees grow well. The heavy texture of this soil is undesirable for growing most truck and fruit crops.

Miller loam.—Numerous small, long, narrow areas of Miller loam are widely scattered throughout the Arkansas River bottom lands. This soil is associated with Yahola very fine sandy loam but lies slightly lower than that soil and slightly higher than Miller silty clay. The soil is lighter in both color and texture and is easier to cultivate than Miller silty clay. Both surface drainage and underdrainage are adequate for the successful growth of all crops common to this county. The soil is calcareous and does not require lime amendments to grow alfalfa.

The surface soil has an average thickness of about 10 inches and consists of dark-brown or reddish-brown calcareous heavy loam. This grades into calcareous dull reddish-brown silty clay loam, which ordinarily reaches to a depth ranging from 30 to 40 or more inches. In places the subsoil is somewhat heavier textured and is reddish-brown silty clay to a depth ranging from 40 to 60 inches. Small areas of other Miller and Yahola soils are included with this soil on the map, as the scale of the map is too small to show them separately.

Miller loam is a good productive soil, well suited to many crops. It is estimated that about 95 percent of it is cultivated. Corn, cotton, and alfalfa are the chief crops grown, and various truck crops also are produced successfully, although the small size of the areas and the distance to market are not everywhere favorable for the growing of truck crops. Practically the same average crop yields are reported as for Miller silty clay.

Verdigris very fine sandy loam.—Verdigris very fine sandy loam is the second most extensive soil of the bottom lands, but its development in Tulsa County is confined to the smaller stream bottoms, principally along Bird Creek, a sluggish, meandering stream, and along Hominy Creek. It consists of alluvial sediments, which occupy the higher strips of land, mainly on the outer side of stream bends. The surface gradually slopes away from the steep banks toward the intervening flat bottom land between the creeks and the adjoining upland. This soil lies from 2 to 6 feet higher than the adjoining soils of the bottom lands, is well drained, and occupies locations that are well suited for the growth of field crops. On the smaller creek bottoms the areas are more nearly flat than on those of the

larger streams. Overflows occur but are of short duration and do not prevent the use of the land for crops.

The lime content of this soil is generally lower than that of other soils in the Arkansas River bottoms, and the reaction is slightly acid in places, owing to the fact that the soil materials are washed largely from acid Prairie soils that are deficient in lime. The surface soil and the subsoil range from slightly acid to neutral. The generally good drainage and the friable subsoil insure the successful growth of all crops common to the county.

This soil occurs in many small areas. Approximately 90 percent is in cultivation. The uncleared areas support a tree growth consisting mainly of elm, red oak, post oak, black walnut, pecan, ash, hickory, cottonwood, hackberry, and honeylocust. The uncleared land is used mainly for pasture and the production of native pecans.

The surface soil of Verdigris very fine sandy loam is brown or grayish-brown very fine sandy loam, ranging from 8 to 14 inches in thickness, which grades into slightly lighter brown or yellowish-brown heavy very fine sandy loam or very fine sandy clay loam. Below a depth of 18 to 22 inches the subsoil in places is light-brown or brownish-yellow loamy fine sand or very fine sandy loam, and at an average depth of about 4 feet the material is more or less stratified with layers that vary in color and texture. At a depth ranging from 4 to 6 feet the material has in places considerable rust-brown and gray mottling. A few small areas of Verdigris fine sandy loam are included with this soil on the map.

Corn is the most important crop, followed by cotton, alfalfa, and oats. Alfalfa ordinarily succeeds without lime, but it is reported that in some places an application of crushed limestone has produced good results. Small grains, such as oats and wheat, are not so commonly grown as on the upland soils. Although yields in dry seasons surpass those produced on the uplands, the vegetal growth of small grains during wet seasons is rank, and they are very susceptible to lodging. This soil is well suited to pecans, peaches, cherries, grapes, plums, small fruits, and berries. Various truck crops, such as potatoes, cabbage, tomatoes, and watermelons, produce good yields, and reports indicate that the use of fertilizers increases yields. Corn yields from 25 to 50 bushels an acre, wheat 12 to 24 bushels, oats 20 to 50 bushels, and alfalfa 3 to 4 tons a season. Average acre yields are about 29 bushels of corn, 25 bushels of oats, 3¾ tons of alfalfa, one-half bale of cotton, and 15 bushels of wheat.

Verdigris loam.—Verdigris loam is a good farming soil occurring mostly on the bottom lands of Bird and Mingo Creeks and to less extent on the bottoms of smaller creeks. Like Verdigris very fine sandy loam, this soil occupies the higher situations along the smaller streams, generally bordering areas of that soil. Surface drainage and underdrainage are good.

This soil differs mainly from Verdigris very fine sandy loam in having a darker surface soil and a heavier subsoil. The surface soil is dark-brown loam or heavy loam, about 12 inches thick. It grades into brown silty clay loam or clay loam, which is underlain, at a depth of 18 to 20 inches, by dark-brown or very dark brown silty clay or clay. In some places the subsoil is not so heavy or so dark-colored. Gray, yellow, and rust-brown mottling is noticeable in the lower part of the subsoil. The darker areas border Mingo Creek,

where the sediments are derived in part from the Summit soils; consequently the lime content here is slightly higher, making such areas somewhat better suited to the production of alfalfa than areas where the soil has a lower lime content.

About 95 percent of the land is cultivated, and the rest supports a tree growth and is used mainly as woodland pasture and for the growth of native pecan trees. Although the more common crops, such as corn, cotton, oats, and alfalfa, predominate, this soil has a wide range of adaptability. Such truck crops as potatoes, tomatoes, cabbage, peas, sweet corn, and melons produce good yields. Berries, grapes, and orchard crops also do well. About the same or slightly higher crop yields are reported as on Verdigris very fine sandy loam.

Verdigris silty clay loam.—Verdigris silty clay loam is most extensive along the Bird and Mingo Creeks bottom lands in the northern part of the county. The surface is almost flat. Bordering Lightning silty clay loam, underdrainage is not so good as in the other Verdigris soils.

The surface soil consists of dark-brown silty clay loam, grading, at a depth of about 10 inches, into dark-brown or brown crumbly silty clay or clay. Ordinarily, at a depth ranging from 18 to 30 inches, considerable gray and rust-brown mottling is noticeable, but in other places brown clay loam continues to a depth of 36 or more inches with very little change. The surface soil contains considerable organic matter and is easily cultivated. The surface soil is slightly acid, and the subsoil is slightly acid to neutral.

Only about one-half of the total area is cultivated, and the rest is used as woodland pasture and for growing native pecan trees. The tree growth consists of oaks, elm, pecan, locust, ash, hawthorn, hackberry, and other trees. The chief crops are corn, alfalfa, cotton, and oats. Some truck farming is carried on. Acre yields average about 26 bushels of corn, 31 bushels of oats, three-eighths bale of cotton, 28 bushels of grain sorghum, 4 tons of alfalfa, and 14 bushels of wheat.

Osage silty clay loam.—Osage silty clay loam consists of alluvial soil materials transported from the limestone upland soils—Summit soils—and deposited in the bottom lands of some of the smaller streams. The larger areas lie about 3 miles northwest of Bixby, 2 miles north of Alsuma, 3 miles northeast of Skiatook, and just north of Glenpool.

The surface soil is very dark brown or dark grayish-brown silty clay loam ranging from 10 to 15 inches in thickness. This material grades into very dark grayish-brown silty clay or clay, which continues to a depth of 26 to 30 inches with little gradation of color or texture. In places, however, the lower part of the crumbly silty clay or clay subsoil is grayish brown or even dark grayish drab. In a few places along the Arkansas River bottom land south of Bixby, this soil occupies small colluvial fans consisting of uniform olive-gray silty clay loam and lying from 2 to 10 feet above the main level of the Arkansas River alluvium. The lighter color is due to sediments transported from the areas of shallow Summit soil on the adjoining upland.

The total acreage of this soil is small. Ordinarily both the surface soil and the subsoil are noncalcareous but probably basic to neutral

in reaction. Approximately 70 percent of this soil is cultivated, and the rest is used as woodland pasture.

This is a productive soil, especially well suited to the growth of corn and alfalfa—the main crops. The content of organic matter, nitrogen, and lime is apparently somewhat higher than that in the Verdigris soils, and yields are equally as high as, or higher than, the yields obtained on those soils, with the exception, perhaps, of the small areas southwest of Bixby. Corn yields probably average about 26 bushels an acre, oats 30 bushels, alfalfa 4 tons, and cotton three-eighths bale.

Osage silty clay.—The surface soil of Osage silty clay is dark grayish-black silty clay, moderately crumbly when moist but very plastic and sticky when wet. It is about 10 inches thick and grades into grayish-black heavy silty clay that contains some small specks of rust brown. The lower part of the subsoil is, in most places, gray or slightly bluish gray. Both the surface soil and the subsoil are about neutral in reaction. The lower part of the subsoil, however, is slightly calcareous in places.

This soil is difficult to cultivate but ordinarily breaks down readily under favorable moisture conditions. Surface drainage and underdrainage are slow, and in places artificial drainage would be beneficial. The largest areas are 2 miles northeast of Collinsville along the Caney River, and a few areas are in the northwestern part of the county.

Because of the overflow hazard, only about 20 percent of this soil is cultivated, and the rest supports a tree growth of native pecan, hackberry, elm, haw, ash, chinquapin, and Texas oak or spotted oak. On the better drained areas the crops grown are mainly corn, cotton, alfalfa, and oats, which produce good yields, although probably averaging somewhat less than those produced on Osage silty clay loam. The present unfavorable conditions of drainage and damage from overflows make the growth of crops on this soil somewhat hazardous.

POORLY DRAINED ALLUVIAL SOILS

Poorly drained alluvial soils are comparatively inextensive and belong to the Lightning and Perry series. Because of the generally flat surface of these soils, both surface drainage and underdrainage are very inadequate. Ordinarily these soils occupy the smooth low-lying flats adjoining the upland farthest from the existing streams. During periods of overflow the movement of water is slow, and these soils are the last to drain. The prevailingly wet condition in early spring is not favorable for cropping. Artificial drainage on these comparatively small areas would be costly, and their productivity probably does not justify the expenditure. The soils are acid and tend to crust after drying. Only about 15 percent of the land is cultivated.

The Lightning soils have gray or brownish-gray moderately heavy surface soils and moderately heavy or heavy compact brownish-gray mottled noncalcareous subsoils. The Perry soils have gray surface soils and gray or bluish-gray clay subsoils with considerable light-brown and rust-brown mottling and calcareous reddish-brown substrata.

Lightning silty clay loam.—Lightning silty clay loam occurs on the smaller creek bottoms of the county, mainly along Bird Creek in the northern part and Ranch Creek near Owasso. It occupies the more nearly flat and somewhat lower situations than the other soils of the smaller creek bottoms. The surface is smooth and apparently has less gradient for run-off than most other soils in the county.

The surface soil consists of a layer of slightly brownish gray to rather dark gray silty clay, 8 to 10 inches thick, which grades into brownish-gray silty clay or clay containing numerous light-brown and rust-brown markings. At a depth ranging from 20 to 30 inches the soil material consists of heavy compact grayish-brown or dark grayish-brown clay containing numerous markings or mottlings like those above and numerous small semihard brown pellets or accretions. Below this and extending to a depth of 60 inches, the clay has a more decided gray cast with similar mottling and small pellets. In some places the material is darker colored in both surface soil and subsoil than the layers described above, but when thoroughly dry it is very hard and intractable and has a decided gray cast. In places white crystals resembling calcium sulfate are present.

Because of imperfect surface drainage and underdrainage, only about 15 percent of the soil is cultivated. The surface soil has a tendency to run together and become hard on drying after a rain, and if not worked at the right time it becomes very cloddy. Good tilth is very difficult to maintain. Both surface soil and subsoil are acid. Only a small excess of surface water may cause considerable injury to young crops. Average yields of corn and cotton are lower than those produced on any of the well-drained bottom-land soils. The greater part of this soil—about 85 percent—is utilized for grazing, to which use it seems best suited. Most of the areas are either treeless or have a scattered growth of pecan, persimmon, hawthorn, and elm.

Corn and cotton are grown to a small extent on adequately drained fields, but yields are low and vary considerably. Yields of corn probably average about 12 bushels an acre, oats 16 bushels, grain sorghums 15 bushels, and cotton one-fourth bale. Even with adequate artificial drainage, this soil is, at best, only fairly productive. Apparently it is best suited to grass and hay crops.

Lightning silty clay.—The 10- to 15-inch surface soil of Lightning silty clay is dark grayish-brown silty clay. It grades into gray or slightly dark bluish-gray dense silty clay containing some rust-brown and light-brown mottling. The lower part of the subsoil is essentially the same as the upper part and contains numerous dark semihard pellets and, in places, fine white crystals, which probably are calcium sulfate. The tests made do not show the presence of lime, even in the lower part of the subsoil, which indicates a slight to moderately acid condition.

This soil is not very extensive, and probably not more than 15 percent is cultivated. It is difficult to crop, owing to the heavy texture and imperfect drainage. The principal areas are in the Bird Creek Valley near Sperry and Skiatook and in a few places on Ranch Creek, especially west of Owasso. The soil occupies slightly depressed or very flat bottom lands, where overflows occur occasionally and natural drainage is very inadequate. Crops, therefore, are very uncertain. In places surface ditches are provided for drainage.

The best use of this soil is probably for grazing. The uncultivated areas now support a good grass cover of various coarse grasses common on flat poorly drained areas. Elm, hawthorn, and persimmon trees are thinly scattered over the land.

Perry clay. The surface soil of Perry clay is grayish-brown or dark grayish-brown mottled heavy silty clay, about 12 inches thick, grading into dark-gray clay containing rust-brown, yellowish-brown, or slightly bluish gray mottling. In most places reddish-brown or dull-red clay underlies this soil at a depth of 2 to 3 feet, but in a few places in the lower situations, such as the cultivated area south of Bixby, the gray mottled subsoil layer is thin.

This soil occurs only in a few small areas in the Arkansas River flood plain, the larger areas lying 1 mile northeast of Red Fork, 1¼ miles southwest of Bixby, and 2½ miles southwest of Sand Springs.

Practically all of the areas support a tree growth consisting mainly of hackberry, locust, elm, ash, water oak, chittamwood, and a few pecan trees. With adequate drainage, this soil is productive and suited to the production of sorghums, corn, cotton, tame grasses, and other field crops. Owing to the small isolated areas of this soil and the expense of ditching the considerable distance to the Arkansas River, drainage ditches have not been provided. At present, grazing seems to be the most practical use of the soil.

FORESTED UPLAND SOILS WITH FRIABLE SUBSOILS

Forested upland soils with friable subsoils include well-drained light-colored sandy soils having crumbly permeable subsoils. These soils have been developed mostly from very old and extremely high alluvial deposits bordering the present Arkansas River flood plain. Hanceville fine sandy loam, however, is developed mainly from residual fine-grained sandstone. The group includes members of the Teller, Dougherty, Stidham, and Hanceville series.

The surface soils are fine sandy loams, very fine sandy loams, and loamy fine sand, and the loose friable fine sandy clay subsoils insure not only easy tillage but also excellent internal drainage. Where proper care and management is not exercised, some of these soils are injured by wind and water erosion.

These soils are moderately to highly productive and are suited to corn, cotton, and grain sorghums, rather than to small grains. They are also well suited to various truck crops, vegetables, orchard crops, berries, and grapes, because of favorable soil characteristics. They respond well to fertilizers but require careful management.

The Teller soils have brown light-textured surface soils and friable reddish-brown sandy clay subsoils. The Dougherty series includes light-colored forested soils developed on high old terraces of the Arkansas River Valley, associated with and developed from about the same parent materials as the Teller soils, but they are more advanced in development, more thoroughly leached, and have less red subsoils. They are moderately productive, rather sloping, and subject to severe erosion. The Stidham soils have surface soils similar to those of the Teller soils, and brownish-yellow friable subsoils. Both the Teller and the Stidham soils occupy high terrace situations and owe their origin, in part at least, to transported sediments of the "Red

Beds" of western Oklahoma. The Hanceville soils are grayish-brown light sandy soils with variable red sandy clay subsoils, which are developed mainly from residual sandstone rock and, in places, some shaly material.

Teller very fine sandy loam.—The 10-inch surface layer of Teller very fine sandy loam is grayish-brown or dark grayish-brown very fine sandy loam. It grades into a 4- to 8-inch layer of brown or reddish-brown rather heavy very fine sandy loam. This gives way, at a depth of 14 to 18 inches, to red or reddish-brown fine sandy clay loam or fine sandy clay. With increasing depth the subsoil gradually becomes reddish yellow. Also it is somewhat more sandy below a depth of 4 feet. The surface soil is loose and easily cultivated, and the virgin soil has a moderate content of organic matter. It absorbs water readily, and the subsoil contains sufficient clay to retain a large proportion of the rain water, thereby assuring favorable response of crops. Inasmuch as the soil is neutral or only slightly acid throughout, alfalfa can be grown successfully.

Included with Teller very fine sandy loam in mapping are small areas of Stidham very fine sandy loam that could not be separated on a map of the scale used. Also included are small areas of Teller fine sandy loam that differ in agricultural value only slightly, if at all, from Teller very fine sandy loam.

Widely separated small areas of Teller very fine sandy loam are on the uplands bordering the Arkansas River Valley. Some of the larger areas lie about 5 or 6 miles north of Bixby and 5 miles south of Broken Arrow. The surface is smoothly undulating, and, for the most part, the slopes have a gradient of less than 4 percent. Surface drainage and underdrainage are good.

Approximately 95 percent of this soil has been cleared of the forest growth and brought under cultivation. The original forest cover consisted chiefly of black oak, and a few scattered trees remain. The soil is productive under proper management and well suited for many farm crops, fruits, vegetables, grapes, berries, and truck crops. Much of the soil is used for the production of truck crops and fruits for local markets, and good yields are reported. Most crops on this soil respond well to fertilization and applications of organic matter. The texture and structure of the soil enable comparatively easy cultivation and assure the maintenance of good soil-moisture conditions. The farm crops grown most extensively are corn and cotton. Although this is not a typical soil for growing small grains, fair yields of wheat, oats, and other grains have been produced. Estimated average acre yields without the use of commercial fertilizers are: Corn, 22 bushels; oats, 26 bushels; cotton, two-fifths bale; grain sorghums, 20 bushels; alfalfa, 3 tons; and wheat, 13 bushels.

This soil is unsurpassed by any other upland soil in this locality. Painstaking terracing has been undertaken by a few of the more far-sighted farmers. This procedure is a valuable asset to this and other sandy-textured soils, in order to conserve the surface soil and its valuable supply of organic matter and other plant nutrients, besides retaining a much greater amount of the local rainfall for growing crops, especially corn.

Dougherty very fine sandy loam.—The surface layer of Dougherty very fine sandy loam is brown or grayish-brown very fine sandy

loam, about 8 inches thick. It grades into subsurface material of yellowish-brown or reddish-brown fine sandy loam. At a depth of 16 to 20 inches this in turn grades into red or reddish-brown very friable fine sandy clay that becomes increasingly sandy with depth. Along deeply cut banks this reddish-brown sandy clay shows only slight variation to a depth of 10 to 15 feet, although the material below a depth of 3 to 4 feet is reddish yellow. Ordinarily the surface soil and the subsoil are noncalcareous, but in most places they are probably neutral or only slightly acid.

Small areas of this soil border the Arkansas River Valley. Some of the larger ones are situated near Tulsa, near Sand Springs, a few miles northeast of Jenks, and from 5 to 6 miles south of Broken Arrow. This soil occupies high rolling areas of old stream terraces comprising soil materials that originated in the "Red Beds" of the West and were deposited as alluvium when the Arkansas River flowed at high flood stages. The relief is rolling, and the slopes range from moderate to steep (some with a gradient of as much as 15 percent). Erosion has modified the original relief, which was that of a smooth and probably higher terrace. Drainage from the surface as well as internally is rapid.

In some of the very small rolling areas of the very high old terrace the soil is fine sandy loam. In such places the color is rather light.

This soil is highly susceptible to erosion, and gullies usually form after several years of cropping unless proper terraces and baffles are first constructed. Continual cropping to corn and cotton without control of erosion possibly will lead to abandonment of this soil in 15 to 30 years. The construction of proper terraces and permanent baffles and the use of manure and green-manure crops, on the other hand, will maintain a good state of productivity indefinitely. The future value of this land depends almost entirely on the care and treatment it receives during the 10 to 15 years after it is put under cultivation.

Approximately 80 percent of this soil is cultivated. Corn, cotton, and melons, with a few patches of alfalfa and some truck crops, are the chief crops grown. Yields are lower than those obtained on Teller very fine sandy loam. On new lands melons produce excellent yields. Because of the friable very fine sandy clay subsoil, grapes are well adapted, but not many plantings have been made. Peach, cherry, and apple trees grow well and are long-lived under good care and management. Various kinds of grasses, shrubs, flowers, and ornamental trees do well, as indicated by beautiful lawns in Tulsa and elsewhere on this soil. The soil is easily worked and responds well to fertilization. From local information it is estimated that the average acre yields over a 10-year period are: Corn, 18 bushels; oats, 20 bushels; cotton, one-fifth bale; grain sorghums, 17 bushels; alfalfa, 2½ tons; and wheat, 9 bushels.

Stidham very fine sandy loam.—The 10-inch surface layer of Stidham very fine sandy loam is dark-brown or grayish-brown very fine sandy loam. It grades into a subsurface layer of grayish-brown or light-brown silty clay loam or heavy very fine sandy loam. Below a depth of about 20 inches this in turn grades into yellowish-brown or brownish-yellow fine sandy clay. In places, at a depth ranging from 30 to 40 inches, the material is slightly mottled with gray.

Both surface soil and subsoil are friable and permeable, and the clay content of the subsoil is sufficient to allow considerable storage of soil moisture as a reserve for growing crops.

This soil is developed in small areas, chiefly in the southeastern part of the county. The largest bodies are about 4 miles northeast of Bixby, and several are just north of the Arkansas River Valley in the vicinity of Sand Springs. The soil occupies very high terraces of old Arkansas River alluvium.

The surface is smoothly undulating, and most of the slopes are rather gentle, probably few being greater than 3 or 4 percent. Surface drainage and underdrainage are very good. Erosion may be severe if the surface is left unprotected, although clean-tilled crops are grown successfully without rapid losses of soil through erosion.

Practically all of this soil is in cultivation, as it is a strong highly productive soil with a wide range of crop adaptability. Corn, cotton, sorghums, and truck crops, with some fruits and vegetables, are the principal crops, but some alfalfa and small grains are grown. Less than 5 percent of the land remains in native forest of black oak and a few other trees. Some areas of the soil possibly supported only a scant tree growth. According to estimates made from information furnished locally, yields of corn average about 25 bushels, oats 26 bushels, cotton two-fifths bale, grain sorghums 24 bushels, alfalfa 3¼ tons, and wheat 14 bushels an acre.

Stidham fine sandy loam.—The 12-inch surface layer of Stidham fine sandy loam is brown or grayish-brown fine sandy loam. It grades into brown or yellowish-brown silty clay loam or heavy fine sandy clay loam, which gives way to yellowish-brown or brownish-yellow fine sandy clay. This material begins at a depth ranging from 20 to 24 inches and continues to a depth of several feet. The soil is friable, and both the surface soil and the subsoil are permeable. In places small areas of Stidham sandy loam are included. The included soil is somewhat similar to Stidham fine sandy loam, except that the sandy material is coarser and all the soil gradations are more sandy.

This is not an extensive soil. Several of the larger areas are in the southeastern part of the county from 4 to 7 miles northeast of Bixby, southeast of Tulsa, and several miles northeast of Jenks. The soil occupies the high terrace of ancient alluvium bordering the Arkansas River Valley. A few small areas are at a lower level on low terraces bordering the lower flood plains of small creeks in the western part of the county.

The surface is smooth, and the slopes are very gentle. Drainage is very good from the surface and internally.

This is a very good soil for general farm, truck, and fruit (pl. 2, *C*) crops, and it is utilized for such crops. Practically all of it is in cultivation. The same crops are grown and practically the same yields are obtained as on Stidham very fine sandy loam.

Stidham loamy fine sand.—The surface layer of Stidham loamy fine sand is grayish-brown fine sand that is very slightly loamy. In virgin areas this layer is only 5 or 6 inches thick, but in cultivated areas, where the organic matter has been worked deeply into the soil, the surface layer is from 8 to 12 inches thick. This material grades into grayish-brown or grayish-yellow fine sand, the yellow increasing

with depth. Below a depth of 2 to 3 feet the subsoil is pale grayish-yellow or yellow fine sand, and this material continues to a depth of many feet.

In some small depressions the surface soil is dark fine sandy loam, about 15 inches thick, underlain by gray fine sandy clay loam. This is a phase of Stidham fine sandy loam that is of too slight extent to justify separation. These imperfectly drained areas are 3 miles east of Jenks in sections 22 and 27.

Stidham loamy fine sand is inextensive. The small bodies are near the Arkansas River Valley, only in the southern and extreme western parts of the county. The largest areas are about 4 miles southeast of Jenks and 4 miles southeast of Keystone on high terraces of ancient alluvium deposited by the Arkansas River.

This soil apparently is low in organic matter and in some essential plant nutrients. The surface is smooth, with the exception of small drifted strips in some unprotected cultivated fields. In general, drainage is very good, as it is effected rapidly by underdrainage through the porous surface soil and subsoil material. Although this is a rather thin soil, approximately 90 percent of it is in cultivation, and the rest supports a native forest mainly of black oak and blackjack oak. Corn, cotton, and sorghums are the chief farm crops, but watermelons, sweetpotatoes, peaches, and plums are grown successfully. Local reports indicate that the soil is not so well suited to general farm crops as to vegetables and fruits, although amendments of commercial fertilizers, manure, and other organic matter are essential for increasing crop yields. Estimates of average acre yields without special fertilization are: Corn, 8 bushels; oats, 12 bushels; cotton, one-eighth bale; and grain sorghums, 10 bushels.

Hanceville fine sandy loam.—In virgin areas Hanceville fine sandy loam is gray or grayish-brown loamy fine sand to a depth of about 4 inches, where it is underlain by yellow or reddish-yellow fine sandy loam. The red fine sandy clay subsoil begins at a depth of 14 to 18 inches and merges with disintegrated or partly disintegrated sandstone at a depth ranging from 3 to 5 feet. Where cultivated, the surface soil is from 8 to 12 inches thick, owing to an admixture of organic matter to a greater depth than under natural conditions of development under the forest growth of post oak, blackjack oak, and a few other deciduous trees. In a few small areas the sandstone lies within 18 to 24 inches of the surface, and these areas would be separated as a shallow phase were they of sufficient extent. In the older cultivated areas the plowed surface soil has a red hue, owing mainly to the effects of erosion.

Widely separated narrow strips of this soil are in the southern and western parts of the county. Several of these small areas are about 5 miles south of Bixby and several miles southwest of Sand Springs. Most of these narrow strips along drainage divides form crests of ridges bordering slopes, which are mapped as Hector stony fine sandy loam and rough stony land (Hector soil material) and on which sandstone is exposed. The surface is gently to moderately sloping. Where the soil is unprotected, erosion is severe and gullies form quickly.

Probably 60 percent of this soil is cultivated; and corn, cotton, and sorghums are the principal crops. The soil is fairly well suited to

vegetables and fruits, which are grown to a small extent. Sweetpotatoes, peanuts, watermelons, peaches, and similar crops return fair yields. Berries, especially strawberries, do well in some places. A fairly good quality of sirup is made from sorgo by some farmers. For best results the soil requires applications of organic matter. Various organic manures and commercial fertilizers cause a rapid response in growing crops, especially when moisture conditions are favorable. From local reports, the estimates of average acre yields for the unfertilized soil are: Corn, 13 bushels; oats, 17 bushels; cotton, one-fifth bale; and grain sorghums, 15 bushels.

SOILS GENERALLY UNSUITED FOR CULTIVATION

Soils generally unsuited for cultivation include those that show very slight soil development and only a faint imprint of the regional environment in the soil profile. The soils are either so light, loose, and deeply sandy or so eroded and shallow that they have little value for cultivated crops.

Although they can be considered as mechanically arable, the unfavorable physical conditions for growth of plants and the scant supply of available plant nutrients make these soils practically unfit for cultivation except for a very few crops. Only under the best climatic conditions and with much effort and cost to modify the soils and increase the supply of plant nutrients, can crops be grown successfully, most of the time with little or no profit. The soils may be considered submarginal for most crops and marginal for a very few crops. In most places the use of these soils for grazing or forestry would probably not be very satisfactory.

This group includes Stidham fine sand, Talihina silty clay loam, Collinsville very fine sandy loam, Yahola loamy fine sand, and Verdigris loamy fine sand. They range from deep fine sand to shallow silty clay loam.

Stidham fine sand.—The surface soil of Stidham fine sand, in virgin areas, is grayish-brown fine sand slightly darkened with organic matter from leafmold of the oak trees, which comprise the principal native vegetation. Here, the surface soil is about 4 inches thick, but in cultivated fields the surface soil is gray or grayish-brown fine sand about 8 inches thick. The surface soil is loose and incoherent and contains very little organic matter. It grades into pale-yellow or grayish-yellow loose fine sand, which continues to a depth of several feet. In places a layer of yellow fine sandy clay lies within 3 feet of the surface.

The larger areas are from 2 to 4 miles southeast of Jenks and in the extreme western part of the county from 2 to 4 miles east of Keystone. This soil is associated with other soils of the Stidham series and with the Teller soil of the high Arkansas River Valley terraces. The topographic features range from rolling to steep in places. The unprotected soil drains rapidly, and heavy rains cut deep gullies in the bare soil. The soil is highly absorptive, and underdrainage is rapid. Very little of the soil—about 10 percent—is in cultivation, and the growth of black oak, blackjack oak, hickory, elm, and other trees remains in a more or less thinned cover, with an intervening sparse cover of coarse bunchgrasses, which provide some grazing, although the grazing value of these grasses is low.

The few cultivated areas are on gentle slopes, and these are highly susceptible to drifting from heavy winds when the surface is bare. On the steep slopes cultivation is difficult. Proper terracing and contour cultivation are necessary to prevent the disastrous effects of erosion.

The small acreages devoted to corn, sorghums, and vegetables return low yields. Probably the soil is best suited for watermelons, peanuts, sweetpotatoes, berries, peaches, and plums, but yields are low and uncertain without the use of fertilizers. It is doubtful whether any crop could be grown successfully in most places without applying fertilizers or organic matter in some form.

Talihina silty clay loam.—Talihina silty clay loam is a thin eroded Prairie soil developed over weathered shale, which lies from 2 to 5 feet below the surface in most places. The surface soil is brown or grayish-brown silty clay loam and has a rather slick feel when moist, owing to the presence of very finely divided shale particles. It ranges in thickness from 5 to 10 inches and grades into brown, light olive-brown, or reddish-brown silty clay containing fine particles of shale, giving the fine earth material a slick greasy feel. This, in turn, grades, at a depth of 15 to 20 inches, into olive-green or gray clay intermixed with broken shale fragments. A slightly weathered bed of shale is reached at a depth ranging from 2 to 5 feet. A few small flat sandstone fragments are scattered over the surface in many places.

Small areas of this soil are in the northern part of the county, mostly east, northeast, and southeast of Skiatook and 5 to 6 miles northeast of Broken Arrow. Most of the soil has a native grass cover and is used for pasture, and some of the larger areas are fenced for the grazing of range beef cattle. The moderately thick growth of grasses consists largely of coarse bunchgrasses, such as species of *Andropogon*. The soil in cultivation, which represents approximately 20 percent of the total area, is cropped chiefly to small grains and sorghums, but yields are not high. The soil is thin and subject to erosion, and in most places it is probably best suited for grazing.

Collinsville very fine sandy loam.—Collinsville very fine sandy loam is a shallow soil developed over sandstone. The surface soil resembles that of Bates very fine sandy loam, but the surface soil and the subsoil are thinner and sandstone lies much nearer the surface than in the Bates soil. The surface soil is brown very fine sandy loam, ranging from 8 to 12 inches in thickness, in places containing fine and small fragments of brittle sandstone. This grades into broken stony material containing yellow or yellowish-brown fine earth with a fine sandy loam or fine sandy clay loam texture. In many places the subsoil is lacking, and the surface soil rests directly on the more or less weathered and disintegrated sandstone beds. The depth to rock varies considerably with the slope. In places the substratum above a depth of 40 inches has shaly clay interbedded with the layers of broken sandstone.

In an area extending from 1 to 3 miles north of Broken Arrow, the soil differs from the typical soil in that the soil material is decidedly more cherty and the surface soil is less sandy. The weathered remnants indicate that the parent rock consisted partly

of thin interbedded limestone as well as sandstone and shale material, but it has disintegrated, leaving the cherty noncalcareous remnants. The soil in this area is slightly darker and more permeable than elsewhere and has a slightly higher cropping value, but, owing to its slight extent, it is included with Collinsville very fine sandy loam.

Collinsville very fine sandy loam is associated with Bates very fine sandy loam in many small areas widely scattered over the prairies throughout the county, especially in the vicinity of Collinsville, a few miles east of Skiatook, near Tulsa, and near Jenks. This soil occupies crests of narrow ridges and rolling areas with moderate to fairly steep slopes. Surface drainage is rapid, and erosion is severe. The loose porous subsoil allows free percolation of water.

Only small areas, occurring mainly as parts of fields occupied by deeper soils, are in cultivation. Possibly about 35 to 40 percent of the combined areas is cultivated. This soil is considered best suited to pasture and is used chiefly for that purpose. Although the dominant grasses are not very nutritious, a moderate cover of coarse bunchgrasses grows on the soil. Some of the essential nutrients are deficient, and, owing to loss of rain water by run-off or percolation, the supply of moisture is often too low for crops to withstand very dry conditions. Grain sorghums and sorgo probably do better than most cultivated crops. Some fruits, berries, grapes, and vegetables can be grown for home use with careful attention given to fertilizing the soil and adding organic matter.

Yahola loamy fine sand.—Yahola loamy fine sand is the lightest and loosest soil of alluvial materials along the Arkansas River. It consists of red and brown fine sand and very fine sand with a slight admixture of silt. The surface soil is light-brown or pale reddish-brown loamy fine sand, about 12 inches thick, grading into light-brown or light reddish-brown fine sand which, below a depth of 3 to 4 feet, is rather loose grayish-yellow or grayish-brown fine sand. In places both the surface soil and subsoil materials are calcareous. The reaction, however, is probably basic in most places.

Irregular spots of slightly heavier and also lighter textured material occur, and irregular slightly billowy areas represent mixed soil material deposited by swift overflow currents near the river.

This soil occupies a small total area in the Arkansas River flood plain. Most of the areas are on the lower bottom-land benches adjacent to the channel of the Arkansas River. The larger areas are near Jenks, Bixby, and Tulsa. The surface features range from a succession of low narrow hummocky ridgelike areas to those that are comparatively smooth or nearly flat. Occasional overflows reassort the materials and add fresh deposits. The material is so loose that it drifts easily in heavy winds, in places where it has no protective cover. Surface drainage is good, and underdrainage is very free.

Probably about 20 percent of the soil is cultivated to vegetables, peanuts, sweetpotatoes, and watermelons, and other truck crops are grown on the smoother areas. Heavy applications of manure are reported to increase yields of truck crops greatly. A few other crops grown in small areas produce low yields. Plums, some berries, and grapes probably would produce fair yields. There is a deficiency of

some essential mineral plant nutrients and organic matter, and the loose porous condition is unfavorable for permanent improvement.

Verdigris loamy fine sand.—The 10- to 15-inch surface soil of Verdigris loamy fine sand is light-brown loamy fine sand. It grades into light-brown, yellowish-brown, or brownish-yellow loose fine sand that continues to a depth of several feet. The texture of the subsoil is variable, and in places layers of heavier textured materials are present at various depths. The reaction is slightly to medium acid. Owing to occasional overflow, the areas of this soil include spots of heavier or lighter textured material.

Very small areas border Bird Creek in the northern part of the county, the typical soil occupying the inner bends of the meandering channel of the creek. The uneven and bumpy surface is due to sedimentation of coarse and fine materials from irregular swift currents of the stream. Surface drainage is very good, and underdrainage is rapid.

Small areas bordering the upland of the Arkansas River Valley, mapped with this soil, consist of sandy materials washed from local upland slopes and spread in fans over areas of Lonoke very fine sandy loam. These areas represent sandy materials carried mostly from the high very old sandy terraces, and other local fine materials have been carried by creeks originating in the prairie section.

Most of Verdigris loamy fine sand is not cultivated; the small cultivated fields comprise less than 10 percent of the total area of this soil. The rest supports a virgin growth of ash, maple, sycamore, cottonwood, elm, hackberry, and pecan trees. The soil is not highly productive, although a number of crops can be grown. Sorghums and various truck crops probably can be most satisfactorily grown, and in certain locations alfalfa probably would return low yields. Pecans should do well. The areas mapped with this soil in the Arkansas River Valley are somewhat more productive and are used fairly successfully for some of the ordinary farm crops.

NONARABLE SOILS AND MISCELLANEOUS LAND TYPES

The nonarable soils and miscellaneous land types are so stony, shallow, or steep that cultivation is practically impossible and would still be so even if the thinly developed soils were sufficiently productive to produce good yields of crops. This land can be used only for grazing and producing firewood, but most of it is not highly valuable for these purposes, as the native grasses are not highly nutritious and the trees are not very valuable for firewood.

Talihina stony clay loam, Denton stony clay loam, Collinsville stony fine sandy loam, Crawford stony loam, Hector stony fine sandy loam, rough stony land (Hector soil material), rough gullied land, mine dumps, and riverwash comprise this group.

Talihina stony clay loam.—Talihina stony clay loam is brown or reddish-brown heavy clay loam or silty clay loam to a depth of 6 to 8 inches, grading into brown or reddish-brown clay that contains enough fine shale particles to give the material a slick greasy feel. Flat fragments of hard sandstone are strewn over the surface and in the surface layer, but they do not occur in the subsoil. The subsoil grades, at a depth ranging from 2 to 4 feet, into beds of olive-gray shale.

The largest areas occur in the northern part of the county in a broken belt extending northeastward from a point about 4 miles northeast of Sperry to the northern county line. A few areas are in the southern and western parts, two lying 2 miles south of Glenpool and one 4 miles southwest of Sand Springs. The land is rolling to strongly rolling and hilly, and drainage from the surface is rapid. This soil supports a fairly heavy growth of native prairie grasses, largely coarse bunchgrasses, such as species of *Andropogon* and *Panicum*, and some grama grasses. All the land is grazed and is considered valuable for this purpose.

Denton stony clay loam.—Denton stony clay loam, although not rough or steep in many areas, is so stony that cultivation is impossible. The fine-earth material is black or dark-brown clay loam, ranging from 2 to 8 inches in thickness. In some places this rests directly on limestone; elsewhere it grades into dark-brown crumbly clay, which rests on limestone at a depth ranging from 1 to 3 feet. Large and small limestone fragments are numerous throughout the surface soil and the subsoil, and massive beds of the hard limestone outcrop at the surface in many places. Probably from 30 to 40 percent of the surface layer consists of stones, either loose or as outcropping beds and ledges. In places small areas of Denton stony loam are included on the map with this soil.

Small areas of this soil are widely scattered throughout different parts of the county. Some of the larger ones are in the eastern part a few miles southeast of Owasso, and others are in the western part, just south of the Arkansas River from Sand Springs to the western county line.

The surface ranges from smoothly undulating to rather steep and in places is blufflike. Erosion is active to some extent, although the vegetation of bunchgrasses and grama grasses holds the soil rather well. On steep slopes and narrow bluffs, outcrops of solid thick beds of limestone are indicated by rock outcrop symbols on the map. Some of these areas would have been separated as rough stony land (Denton soil material) had they been of sufficient extent. These steep slopes and bluffs support a growth of trees, mainly elm, hackberry, chinquapin oak, redbud, dogwood, hawthorn, and chittamwood, together with shrubs of sumac, coralbush, and others.

This soil is only moderately good for grazing, as a large proportion of the surface is occupied by stony material. The limestone is a valuable source of building material and road material, as well as lime or crushed limestone for use on farm land that may require liming.

Collinsville stony fine sandy loam.—The 10-inch surface soil of Collinsville stony fine sandy loam is brown fine sandy loam. Many small and some large fragments of shaly sandstone are present in this layer. The surface soil grades into light-brown partly disintegrated sandstone containing little fine-earth material. Small rounded sandy mounds occur in places.

Many small areas of this soil are scattered throughout the prairie sections of the county. The larger ones are within a few miles of Glenpool and in the northeastern part within a few miles of Collinsville. The soil occupies high rolling positions and ridges and has rapid surface drainage. Coarse bunchgrasses provide fairly good

grazing for livestock, and the land is used entirely for that purpose. Summer-grazed cattle are said to require from 6 to 8 acres a head for the season.

Crawford stony loam.—The surface soil of Crawford stony loam is reddish-brown heavy very fine sandy loam ranging from 6 to 10 inches in thickness. This grades into red crumbly clay or clay loam, which in most places rests on limestone at a depth ranging from 1 to 2½ feet. The surface is strewn with stony material in the form of loose fragments and smooth boulders, and stone outcrops in ledges on steep slopes.

This soil occupies only a few small areas, most of which are from 4 to 6 miles north of Broken Arrow. Some bodies occur several miles southwest of Sand Springs.

Crawford stony loam is developed on undulating to steep prairie land and has rapid drainage. Trees, mostly post oak, blackjack oak, and elm, have encroached on some of the steeper slopes, but nutritious prairie grasses cover the smooth prairie areas, which are used entirely for pasturing livestock.

On steep slopes massive outcropping rock strata occupy the land, which would have been mapped as rough stony land (Crawford soil material) had its extent warranted separation.

Hector stony fine sandy loam.—The 4- to 6-inch surface soil of Hector stony fine sandy loam consists of grayish-brown or dark-gray fine sandy loam and contains a large quantity of large and small broken sandstone fragments and finely disintegrated particles of all sizes. This grades into yellow or reddish-yellow fine sand in which broken fragments of sandstone are numerous. At a depth ranging from 12 to 18 inches, this material merges with red sandy clay containing numerous sandstone fragments, a mass of disintegrated sandstone, or more or less weathered solid strata of this stone. The clay in places is mottled gray, yellow, and red below a depth of 2 to 3 feet. In places the sandstone soil and stony material are underlain, at a depth of 2 feet or more, by shaly clay.

This soil occupies small and moderate-sized widely separated areas in the southern and western parts of the county. Some of the larger areas are from 5 to 7 miles southeast of Bixby, southeast of Tulsa, southeast of Glenpool, and from 5 to 10 miles southwest of Sand Springs. It is associated with other forested soils, chiefly rough stony land (Hector soil material), and is of much the same character as that land, except that the slopes are less steep and the stony material is more weathered and disintegrated. The surface ranges from undulating to rolling, and the slopes are only moderately steep. The soil occupies smooth ridge crests and low hills and has rapid surface drainage. Not only is it too stony for cultivation, but the thinly developed soil material contains too small a supply of some essential plant nutrients for profitable yields of farm crops, even if it were free of stony material. The native forest includes mostly post oak, blackjack oak, and some hickory, and, where the tree growth is scant, a moderate growth of coarse bunchgrasses has encroached. Although these grasses are not highly nutritious, they afford some summer grazing for livestock.

Rough stony land (Hector soil material).—Rough stony land (Hector soil material) is rather similar to Hector stony fine sandy

loam except that the slopes are steeper, the terrain is more rugged, and the stony material is more abundant and massive. The fine-earth material between the rocks is grayish-brown fine sand or fine sandy loam a few inches thick, over yellow or red sand or sandy clay.

This is one of the more extensive lands of the county. Many small and some large areas are in the southern and western parts several miles southeast of Bixby and southwest of Sand Springs.

The surface is rolling to hilly, and the slopes are very steep. In some places the slopes comprise bluffs of massive sandstone outcrops, and in other places the lower slopes are largely outcrops of shaly material on which the overlying sandstone boulders have broken and rolled from the higher lying outcrops that cap the shale formations.

The small forest growth, consisting largely of post oak, blackjack oak, hickory, and a few other trees, has little value except for firewood and posts, as most of the larger trees have been removed. The thin stand of grasses, largely coarse bunchgrasses, does not afford a good supply of forage for livestock, although the land is used for pasture.

Rough gullied land.—Rough gullied land designates an incipient form of rough broken land. It comprises narrow strips of eroded, deeply cut soils adjacent to long, narrow gullies near the heads of dry drainage channels, which extend into many areas of smooth prairie land. These strips are more common within areas of Parsons silt loam. The surface soil and much of the subsoil in these strips have been washed away, and most of them have a scant vegetative cover, although some are partly barren. Despite their small size, these irregularities of rough gullied land menace the value of adjacent soils, as they have little or no value for crops or pasture. Control of erosion on this type of land is essential. Rough dams or barriers across the gullies will collect and retain the eroded soil materials from above, allow the gradual establishment of grass, and prevent further destruction of the land.

Some of this land has been fenced and used for grazing, but any attempt to cultivate it generally is a waste of time and work. In its present state this land is practically useless and reduces the value of any farm including it.

Mine dumps.—Mine dumps have been formed by steam shovels or in some other manner of removing the overburden from the underlying coal strata, limestone, or building materials, which lie from 15 to 25 or more feet below the surface. These successive sharp ridges of piled earth and rocks and intervening ditches are of no agricultural value, as they support only a very sparse growth of weeds and grasses. A few berries and grapes have proved partly successful, and in one place a small pecan grove was noticed during this survey. The percentage of raw shale and rock material, however, is too great to allow profitable utilization of such land for agriculture. The main areas of this miscellaneous soil material occur in the vicinities of Dawson and Collinsville. Sweetclover or some pasture crop might grow on these areas.

Riverwash.—Riverwash occupies the main channel of the Arkansas River and lies from 2 to 8 feet above the normal water level of the river. It consists of barren medium to coarse sand and gravel, covered with some debris in the higher places, but the soil material is

not suitable for agricultural use. Moreover, this land is subject to continuous change at each rise of the river. The areas shown on the map, therefore, indicate the relative proportion of movable river-wash within the main river channel. In places large quantities are removed with steam shovels and used in road building and other kinds of construction.

PRODUCTIVITY RATINGS

In table 5 the soils of Tulsa County are listed alphabetically, and estimated average yields of the principal crops are given for each soil. These averages represent production under prevailing practices over a period of years.

TABLE 5.—*Estimated average acre yields of the principal crops on each soil in Tulsa County, Okla.*[1]

Soil (soil types, phases, and land types) [2]	Cotton (lint)	Corn	Oats	Wheat	Grain sorghums	Alfalfa	Hay [3] and/or pasture	Fruits [3] and/or vegetables
	Lb.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Tons*		
Bates fine sandy loam	125	17	22	11	18	[4] 2	Fair	Moderately good.
Bates fine sandy loam, deep phase.	200	20	26	14	22	[4] 2	Good	Good.
Bates silt loam	167	18	28	15	20	[4] 2¼	do	Do.
Bates very fine sandy loam	167	18	25	13	20	[4] 2½	do	Do.
Bates very fine sandy loam, deep phase.	200	22	28	14	24	[4] 2¾	do	Do.
Brewer silty clay	167	28	30	15	26	4	Fair	Fair.
Brewer silty clay loam	250	30	30	16	30	4	Good	Moderately good.
Cherokee very fine sandy loam.	100	12	20	10	15	------	Fair	Poor.
Collinsville stony fine sandy loam.	-----	-----	-----	-----	-----	------	do	
Collinsville very fine sandy loam.	-----	9	12	6	10	------	do	Very poor.
Crawford stony loam	-----	-----	-----	-----	-----	------	do	
Denton stony clay loam	-----	-----	-----	-----	-----	------	do	
Dougherty very fine sandy loam.	100	18	20	10	17	[4] 2½	do	Good.
Fitzhugh very fine sandy loam.	167	20	26	14	22	[4] 2¼	Good	Do.
Hanceville fine sandy loam	100	13	17	-----	15	------	Fair	Fair.
Hector stony fine sandy loam	-----	-----	-----	-----	-----	------	Poor	
Lightning silty clay [5]	100	12	16	-----	15	------	Good	Very poor.
Lightning silty clay loam [5]	100	12	16	8	15	------	do	Do.
Lonoke very fine sandy loam	250	32	30	15	28	4	Very good	Very good.
Miller loam	250	32	30	14	28	4	Good	Moderately good.
Miller silty clay	250	30	30	15	28	4	Fair	Poor.
Mine dumps	-----	-----	-----	-----	-----	------	Very poor	
Newtonia fine sandy loam	125	18	22	10	24	2½	Fair	Moderately good.
Newtonia silty clay loam	200	20	25	15	22	2½	Good	Fair.
Osage silty clay	167	24	28	14	25	4	do	Poor.
Osage silty clay loam	167	26	30	15	28	4	do	Good.
Parsons silt loam	125	15	22	12	18	[4] 1¾	do	Fair.
Parsons silt loam, deep phase.	125	16	24	13	20	[4] 2	do	Good.
Parsons silt loam, slope phase.	100	12	18	10	14	[4] 1¼	Moderately good	Poor.
Perry clay	-----	-----	-----	-----	-----	------	Good	Very poor.
Riverwash	-----	-----	-----	-----	-----	------	-----	
Rough gullied land	-----	-----	-----	-----	-----	------	Poor	
Rough stony land (Hector soil material).	-----	-----	-----	-----	-----	------	Very poor	
Stidham fine sand	-----	-----	-----	-----	-----	------	Poor	Very poor.
Stidham fine sandy loam	200	20	25	14	20	[4] 3	Fair	Good.

[1] These estimates are based on production under prevailing soil-management practices over a period of years, as interpreted from interviews with farmers and observations made during the progress of the soil survey.

[2] The soils are listed in alphabetical order.

[3] Very limited data allow only general comparisons on a local basis as to yields of hay, carrying capacity of pastures, and yields of fruits and vegetables.

[4] These yields for alfalfa apply only when liming is practiced.

[5] The yields apply only to the naturally better drained areas. Other areas are not sufficiently drained to cultivate.

TABLE 5.—*Estimated average acre yields of the principal crops on each soil in Tulsa County, Okla.*—Continued

Soil (soil types, phases, and land types)	Cotton (lint)	Corn	Oats	Wheat	Grain sorghums	Alfalfa	Hay and/or pasture	Fruits and/or vegetables
	Lb.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Tons*		
Stidham loamy fine sand	62½	8	12	-----	10	-----	Poor	Fair.
Stidham very fine sandy loam	200	25	26	14	24	[1] 3	Fair	Good.
Summit clay	167	16	25	14	20	2	Good	Fair.
Summit silty clay loam	167	20	25	14	24	2¾	do	Good.
Talihina silty clay loam	-----	10	12	8	14	-----	Fair	Very poor.
Talihina stony clay loam	-----	-----	-----	-----	-----	-----	Good	
Teller very fine sandy loam	200	22	26	13	24	[1] 3	do	Very good.
Verdigris loam	250	25	27	15	28	4	do	Moderately good.
Verdigris loamy fine sand	-----	-----	-----	-----	-----	-----	Fair	Very poor.
Verdigris silty clay loam	187	22	28	14	25	4	Very good	Moderately good.
Verdigris very fine sandy loam.	250	29	27	15	28	3¾	do	Good.
Yahola loamy fine sand	-----	-----	-----	-----	-----	1½	Fair	Very poor.
Yahola loamy very fine sand	200	26	20	10	30	3½	Moderately good	Fair.
Yahola very fine sandy loam	200	28	23	10	30	3½	Very good	Good.

[1] These yields for alfalfa apply only when liming is practiced.

Yields on a given soil type vary greatly with differences in rainfall and other climatic conditions from year to year and with differences in soil management. Actually, the details of soil management differ from farm to farm, and the estimated yields in table 5 are only approximate as they apply to any particular farm. General farming with a comparatively large proportion of cash crops is the most common type of land use in the county. Considerable livestock is kept on some farms, and in places vegetables are grown commercially. On most farms no definite crop rotation including the growing of legumes is practiced. Manure is commonly used where it is available, but little commercial fertilizer is used except where market-garden crops are grown. These latter crops are grown under intensive practices largely on the Stidham and Teller soils and on some of the soils of the bottom lands. The maintenance of crop yields on most farms depends on the introduction of better practices and improved plant varieties. Without these, crop yields may be expected to decrease gradually.

In order to compare directly the yields obtained in Tulsa County with those obtained in other parts of the country, yield figures have been converted in table 6 to indexes based on standard yields. The soils are listed in the approximate order of their general productivity under prevailing farming practices, the most productive soils being at the head of the table.

TABLE 6.—*Productivity ratings of the soils of Tulsa County, Ok*

Soil [1]	Crop productivity index [2] for—									Rem du soi sus abi
	Cotton	Corn	Oats	Wheat	Grain sorghums	Alfalfa	Hay [3] and/or pasture	Fruits [3] and/or vegetables	General productivity grade [4]	
Lonoke very fine sandy loam	65	65	60	60	70	100	Very good	Very good		Ferti sus floo
Brewer silty clay loam	65	60	60	65	75	100	Good	Moderately good		Ferti or
Miller loam	65	65	60	55	70	100	do	do		Ferti sus sio
Verdigris very fine sandy loam	60	60	55	60	70	95	Very good	Good	4	d
Miller silty clay	65	60	60	60	70	95	Fair	Poor		Ferti or occ
Verdigris loam	60	50	55	60	70	95	Good	Moderately good		Ferti sus sio
Yahola very fine sandy loam	50	55	45	40	75	85	Very good	Good		d
Teller very fine sandy loam [6]	50	45	50	50	60	[7] 75	Good	Very good		Mode fert wh
Stidham very fine sandy loam [6]	50	50	50	55	60	[7] 75	Fair	Good	5	pec tab d
Yahola loamy very fine sand	50	50	40	40	75	85	Moderately good	Fair		Ferti sus floo
Osage silty clay loam	40	50	60	60	70	100	Good	Good		Ferti or occ
Brewer silty clay	40	55	60	60	65	95	Fair	Fair		Ferti or imp
Bates very fine sandy loam, deep phase.	50	45	55	55	60	[7] 70	Good	Good	5	ally Mode
Stidham fine sandy loam	50	40	50	55	50	[7] 75	Fair	do		som d
Bates fine sandy loam, deep phase.	50	40	50	55	55	[7] 50	Good	do		d

Verdigris silty clay loam	45	45	55	55	60	95	Very good	Moderately good		Fertil sion dra
Newtonia silty clay loam	50	40	50	60	55	60	Good	Fair		Mode son
Fitzhugh very fine sandy loam	40	40	50	55	55	[7] 55	do	Good		d
Osage silty clay	40	50	55	55	60	100	Good	Poor		Ferti fect wo
Summit silty clay loam	40	40	50	55	60	60	do	Good	5	Mod wo ero
Bates silt loam	40	35	55	60	50	[7] 55	do	do		d
Bates very fine sandy loam	40	35	50	50	50	[7] 60	do	do		Mod rat
Parsons silt loam, deep phase	30	30	50	50	50	[7] 45	do	do		Mod soil cep
Bates fine sandy loam	30	35	45	45	45	[7] 50	Fair	Moderately good	6	Mod rat tib
Newtonia fine sandy loam	30	35	45	40	60	60	do	do		Mod son
Dougherty very fine sandy loam	25	35	40	40	40	[7] 60	do	Good		Rath rat
Parsons silt loam	30	30	45	50	45	[7] 40	Good	Fair		Mod soil
Summit clay	40	30	50	55	50	45	do	do	6	tib Mod dra
Cherokee very fine sandy loam	25	25	40	45	35	------	Fair	Poor		Mod soil
Hanceville fine sandy loam	25	25	35	--------	35	------	do	Fair	7	Low tili in

[1] The soils are listed in the approximate order of their general productivity under the common practices of soil management, t

[2] The soils are given indexes that show the approximate average production of each crop in percentage of the standard of referen
age yield obtained without use of amendments on the more extensive and better soil types of those regions of the United States in w
are based largely on estimates of yields (see table) as yield data are too fragmental to be adequate.

[3] Data are not sufficient to justify giving indexes in these two columns. The terms used to describe productivity have local r

[4] This classification indicates the general productivity of the soils under common soil-management practices. Refer to the tex

[5] This is a general classification to indicate local opinion as to the suitability of the soils for farming, specialized crops, or grazi
ease of tillage and conservation problems are also considered.

[6] The high ratings of Teller and Stidham very fine sandy loams are due to the ease with which these soils may be worked an
and vegetables.

[7] These yields for alfalfa apply only when liming is practiced.

TABLE 6.—*Productivity ratings of the soils of Tulsa County, Okla.*—C

Soil	Crop productivity index for—									Re d s s a
	Cotton	Corn	Oats	Wheat	Grain sorghums	Alfalfa	Hay and/or pasture	Fruits and/or vegetables	General productivity grade	
Parsons silt loam, slope phase	25	25	35	40	35	[7] 35	Moderately good	Poor	7	Mo t s
Lightning silty clay loam [8]	25	25	30	35	35	-----	Good	Very poor	8	Mo p
Lightning silty clay [8]	25	25	30	-----	35	-----	do	do		
Stidham loamy fine sand	15	15	25	-----	25	-----	Poor	Fair		Lo e
Talihina silty clay loam	-----	20	25	30	30	-----	Fair	Very poor		Lo t
Collinsville very fine sandy loam.	-----	20	25	25	25	-----	do	do		Lo e
Perry clay	-----	-----	-----	-----	-----	-----	Good	do		Mo p
Verdigris loamy fine sand	-----	-----	-----	-----	-----	40	Fair	do	9	Mo o
Yahola loamy fine sand	-----	-----	-----	-----	-----	40	Fair	Very poor	9	Lo p
Stidham fine sand	-----	-----	-----	-----	-----	-----	Poor	do		n Lo e lo
Talihina stony clay loam	-----	-----	-----	-----	-----	-----	Good [9]	-----	9	Lo s
Crawford stony loam	-----	-----	-----	-----	-----	-----	Fair [9]	-----		Ver i
Denton stony clay loam	-----	-----	-----	-----	-----	-----	do.[9]	-----		
Collinsville stony fine sandy loam.	-----	-----	-----	-----	-----	-----	do.[9]	-----		Sto

Hector stony fine sandy loam							Poor [9]		10	Stony
Rough gullied land							do.[9]			Rough
Rough stony land (Hector soil material).							Very poor [9]			Rough
Mine dumps							do.[9]			Rough and
Riverwash									10	Coars rial shif

[7] These yields for alfalfa apply only when limsing is practiced.
[8] These yields apply only to the naturally better drained areas. Other areas are not sufficiently drained to cultivate.
[9] These soils are used almost entirely for grazing. Little or no hay is cut.

The ratings in table 6 compare the productivity of each of the soils for each crop to a standard, namely, 100. This standard index represents the approximate average acre yield obtained without amendments on the more extensive and better soil types of the regions of the United States in which the crop is most widely grown. An index of 50 indicates that the soil is about half as productive for the specified crop as the soil with the standard index. Soils given amendments, such as lime or commercial fertilizers, and special practices, such as irrigation, and unusually productive soils of small extent may have productivity indexes of more than 100 for some crops. The following tabulation gives some of the acre yields that have been set up as standards of 100. They represent long-time average yields of crops of satisfactory quality on the better soils without the use of amendments.

Crop:		
Cotton	pounds	400
Corn	bushels	50
Oats	do	50
Wheat	do	25
Grain sorghums	do	40
Alfalfa	tons	4

The order in which the soils are listed and the general productivity grade are based on a weighted average [6] of the indexes for the various crops, using the approximate areal extent and value of the various crops as bases. Since it is difficult to measure mathematically either the exact significance of a crop in the agriculture of an area or the importance or suitability of certain soils for particular crops, the weightings set up for the natural soil groups were used only as guides. Certain minor modifications dictated by personal judgment were permitted in listing the soils in the order of their general productivity. General productivity grade numbers are determined as follows: If the weighted average is between 90 and 100, the soil type is assigned a grade of 1; if it is between 80 and 90, a grade of 2 is given; etc. The highest productivity grade in Tulsa County is 4, indicating a weighted average between 60 and 70.

It will be noted that the ratings of the soils are rather low in comparison with the better soils of the United States. This is not altogether due to a lack of suitability of the soils in Tulsa County

[6] The weights in percentage given each crop index in order to determine the general productivity grade were, for each soil group, as follows:

Percentage weighting of crop indexes

Soil group	Cotton	Corn	Oats	Wheat	Grain sorghums	Alfalfa	Hay or pasture	Fruits or vegetables
Smooth-lying Prairie soils with moderately heavy textured subsoils	15	35	20	5	5	4	6	15
Soils with dense clay subsoils (Planosols) on smooth upland plains	5	10	25	5	12	3	25	5
Well-drained alluvial soils	25	30	10	2	3	10	10	10
Poorly drained alluvial soils	3	5	5	----	2	----	30	----
Soils with friable subsoils developed under forest on high terraces and uplands	30	20	10	3	5	2	10	20
Soils generally unsuited to cultivation	5	5	15	5	4	----	30	3
Nonarable soils and miscellaneous land types	----	----	----	----	----	----	30	----

to the crops grown or to a lack of fertility. Irregularity of the moisture supply from year to year and lack of intensive methods of soil management account in large part for the comparatively low yields. On the other hand, the fact that a soil is well adapted to a particular crop does not necessarily mean that that crop will be grown extensively on it. Economic considerations, such as the relation of the price of the crop to the cost of production and marketing, are of prime importance.

Productivity tables do not present the relative roles that soil types, because of their extent and the pattern of their distribution, play in the agriculture of the county. The tables give a characterization to the productivity of individual soil types. They cannot picture the total quantitative production of crops by soil areas without the additional knowledge of the acreage of the individual soil types devoted to each of the specified crops.

Economic considerations play no part in determining the crop-productivity indexes; therefore they cannot be interpreted into land values, except in a very general way. Distance to market, relative prices of farm products, and other factors influence the value of land.

The right-hand column summarizes in a simple way the productivity and use capabilities of the various soils by placing them in a few groups on the basis of their relative suitability for farming and grazing. This classification brings out the local opinion as to the relative desirability of the soils for these uses but does not compare them with soils in other parts of the United States. It will be noted that each of the groups or classes may contain more than one productivity grade and that some of the productivity grades are split between two or more classes. This is because the productivity grade is based entirely on productivity, whereas the local classification is based also on the comparative ease of working and conserving the soil and may be influenced to some extent by the location and pattern of the soil types and the kind of use to which they are being put. Teller and Stidham very fine sandy loams are used for intensively cultivated fruit and vegetable crops, and this fact explains in part the high rating given them.

RECOMMENDATIONS FOR THE MANAGEMENT OF THE SOILS OF TULSA COUNTY[7]

Type of farming and soil condition determine to a very great extent the kind of cropping system or fertilizer treatment that should be used in order to maintain or improve the productivity of land. Where there is a local demand for dairy, poultry, or horticultural products, intensive cropping systems frequently are followed on soils that normally should support a more extensive type of agriculture. The natural fertility of soils having similar topographic characteristics is variable; consequently, a varied response may be obtained from the return of organic matter to different soils, especially when natural fertility is high as compared with that of soils containing relatively low quantities of organic matter and nitrogen. Under average conditions dairy farmers are in a good position to main-

[7] By H. J. Harper, professor of soils, Agronomy Department, Oklahoma Agricultural and Mechanical College.

tain the nitrogen and phosphorus content of soil through the purchase of concentrated feeds and the careful preservation of farm manure. A similar condition prevails where poultry or other forms of livestock are raised, whereas farmers who sell grain or cotton are depleting the fertility of their land at a more rapid rate than those who depend on livestock or livestock products as a source of farm income.

Losses of nitrogen, organic matter, and phosphorus that have taken place in the soils of Tulsa County as a result of cultivation are given in table 7.

TABLE 7.—*Losses of plant nutrients in the soils of Tulsa County, Okla., as a result of cultivation*

[Average of 8 comparisons]

Condition of soil	Nitrogen [1]	Organic matter [1]	Total phosphorus [1]	Readily available phosphorus [1]
	Pounds	*Pounds*	*Pounds*	*Pounds*
Virgin	2,810	60,800	490	42
Cropped	1,750	41,200	430	35
Loss	1,060	19,600	60	7

[1] Pounds per acre in soil 6⅔ inches deep.

From the data presented in table 7 it is evident that nitrogen and organic matter are disappearing rapidly from cultivated land, and that the phosphorus content of these soils also has been reduced, as a result of the continued production of soil-depleting crops. Although experiments indicate that the nitrogen content of land in humid sections cannot be increased when it is cultivated every year, more attention must be given to the production of leguminous crops, which will add organic matter and nitrogen to the soil and assist in the development of a more permanent type of agriculture.

CROPPING SYSTEMS FOR SOIL IMPROVEMENT

Where soil conditions are favorable for the production of alfalfa, this crop will add more organic matter and nitrogen to the soil than any other legume that can be grown. Alfalfa also will return a larger net income per acre than most field crops. The objection to alfalfa for soil improvement, however, is that it normally occupies the land for several years; consequently, it is adapted to long rotations ranging from 12 to 16 years. Where large areas are deficient in nitrogen, some other legume must be used in order to obtain an immediate effect. Although alfalfa will not grow naturally on some soils, it can be grown with proper fertilizer treatment where internal drainage is favorable for root development. Two or three tons of finely ground limestone and 300 pounds of superphosphate per acre frequently are needed, in order to provide favorable conditions for the growth of alfalfa on many upland soils. Farmers who purchase alfalfa hay for their livestock should investigate the possibilities of producing alfalfa on their own land at a lower cost through the addition of fertilizer to the soil.

Sweetclover is an excellent crop for soil improvement, but very little direct return can be obtained from this crop unless it can be pastured, although sweetclover seed under present conditions will return about as much net profit per acre as small grain. The chief value of the sweetclover is from the increase in yield of crops planted on the land after the residue from the sweetclover has been returned to the soil. Sweetclover will not grow on acid soil. On soils that are not acid or where lime is applied to correct soil acidity, however, this crop can be grown successfully with a nurse crop by drilling small grain in rows approximately 14 inches apart and scattering inoculated sweetclover seed over the field at the rate of 15 pounds per acre during the latter part of February or early in March. When the surface of the soil has been packed by heavy rainfall, the seedbed should be drilled or harrowed before the seed is broadcast, in order to cover the seed and thus obtain a good stand and prevent loss or uneven distribution of seed by run-off. Oats and barley are better nurse crops than wheat. One or two crops of medium early corn should be grown following the sweetclover, in order to utilize the nitrogen added to the soil by this legume. Small grain sown after sweetclover has been grown may produce so much straw that damage to the crop from lodging will occur. Wheat or rye generally is less subject to lodging than oats or barley.

Where acid soils cannot be limed in order to grow sweetclover or alfalfa, lespedeza sown with small grain is one of the best legumes that can be grown for soil improvement. Lespedeza also provides an abundance of pasture during the summertime when drought does not interfere with its development. This legume can be used to best advantage in a cropping system in which small grain is planted every year. After the lespedeza matures seed in the fall, the land should be disked thoroughly or plowed to a depth of about 3 inches and planted to winter barley or wheat, or a seedbed may be prepared for spring oats during the wintertime. Sufficient quantities of lespedeza seed will be present in the soil after two or three seasons so that reseeding will not be necessary as long as this system is followed. Clipping to control weeds and grass is an essential part of a lespedeza-small grain cropping system. It may be necessary to mow a field two or three times each summer if there is an abundance of tall weeds and grass, which will shade out the lespedeza if they are allowed to grow. If mowing does not control the weeds, a row crop should be planted so that weeds can be controlled by careful tillage.

Several other legumes can be used in cropping systems for this county. Hairy vetch is an excellent winter legume for sandy land, whereas Austrian Winter peas and crimson clover are better adapted to silt loam and clay loam soils. These three crops should be planted in the fall, and their growth will depend to a very great extent on favorable moisture conditions and soil fertility. Vetch can be planted in August or early September, regardless of soil conditions. The other two legumes should not be planted until soil moisture conditions are favorable, which usually is during the latter part of September or early in October. Hairy vetch is superior to Hungarian vetch except on highly productive soil. It will also withstand more cold weather than other winter legumes that have been tested. Winter legumes are of value for pasture or hay, and under an inten-

sive system of farming it is desirable to plant a small quantity of rye or wheat with the vetch or winter peas to support the vines and prevent decay, which will take place if the stems and leaves come in contact with moist soil. It is rather difficult to plant cotton or corn following a winter legume. Sudan grass for pasture can be recommended if moisture conditions are favorable during the month of June so that a good seedbed can be prepared and the crop can be established before hot weather occurs.

Such crops as cowpeas, soybeans, and mung beans are not so valuable for soil improvement under average conditions as legumes planted on soil that is not disturbed during the growing season, because cultivation and tillage during the summer is indirectly responsible for the destruction of large quantities of soil organic matter. On poor sandy land the cowpea is one of the best legumes that can be grown to increase the nitrogen content of the soil. This is especially true where farmers are not financially able to purchase fertilizers or do not realize the importance of applying lime or phosphate, which may be needed to produce maximum yields of sweetclover or hairy vetch. Cowpeas also produce a second growth of forage, which can be used as green manure after the first crop has been removed for hay. When soybeans or mung beans are cut for hay no second growth appears. At present the total acreage of legumes is low as compared with the total acreage of soil-depleting crops grown in the county. In order to maintain the nitrogen content of cultivated soils, at least 20 percent of the cropped land should be planted to legumes each year. If two legumes can be introduced into a cropping system, and if the major part of the residue left by these crops can be returned to the soil, crop yields should be increased in proportion to the amount of nitrogen added as long as climatic conditions are favorable for plant development. Since the sequence of crops may vary for different areas and on different farms in the same area, about the only recommendation that can be made to improve present conditions is to grow a legume at regular intervals in a cropping system, On some of the poorer soils, one-half of the cultivated land should be planted to cowpeas or hairy vetch each year in order to add sufficient nitrogen to the soil to produce maximum yields of crops. Where poor sandy land is used for the production of feed crops, one half of the land should be planted to cowpeas and the other half to grain sorghums. Where poor sandy land is used for the production of a cash crop, such as cotton, one-half of the land should be planted to hairy vetch and followed by cotton. This system will be profitable after the second year, when the residual effect of the vetch appears on the cotton crop. Less labor is required to produce the vetch than the cowpeas in a cowpea-cotton cropping system.

FERTILIZER AND LIME REQUIREMENTS

The fertilizer requirement of a soil depends to a very great extent on (1) the crops that are being grown, (2) the length of time the land has been farmed, (3) the type of farming, and (4) the fertility of the land under virgin conditions. The leaching effect of rainfall, combined with differences in parent material on which soil development occurred, accounts to a very great extent for differences in the

phosphorus content and acidity of soils in this county. Crops like alfalfa and many vegetables require a large quantity of available phosphorus to produce maximum yields. Crops like small grain and corn require a medium quantity of phosphorus, and crops like grain sorghums require a very small quantity of phosphorus for maximum production; consequently, there is a tendency to grow crops that have a low nutrient requirement on poor land, whereas crops having a high nutrient requirement are planted on more fertile soils.

A study of the acidity of soils in Tulsa County indicates that a high percentage of the bottom-land soils along the Arkansas River and smaller tributaries are not acid. Soils developed on weathered limestone or calcareous shale are somewhat variable in reaction, depending on the amount of leaching that has taken place. A majority of the upland soils, which include a large area of high terrace land on the north side of the Arkansas River, are acid. A total of 743 samples of surface soil from different parts of the county have been analyzed for lime requirement. Of these samples, 311 contained sufficient lime for lime-loving crops; 116 were slightly acid; 58 were slightly acid +; 118 were medium acid; 54 were medium acid +; and 86 were strongly acid. A good supply of agricultural limestone is available fro mquarries located along the Arkansas River west of Tulsa and in limestone formations northeast of that city. When soils are slightly acid about 1 ton per acre of finely ground limestone should be applied for crops like alfalfa and sweetclover. For medium acid soils 2 tons should be applied, and for strongly acid soils 3 tons. The quantity of limestone needed depends to some extent on the texture of the surface soil, the acidity of the subsoil, and the crop to be grown. Limestone should be applied in order to provide optimum conditions for the crop having the highest lime requirement in the cropping system. Small grains, corn, and cowpeas give very little response to lime except on strongly acid soils. Sweetclover and alfalfa are most responsive to applications of limestone. Limestone should be thoroughly worked into the plowed layer of a soil in order to be of greatest benefit for lime-loving crops. This can be accomplished by applying the limestone so that the land will be plowed two or three times in preparing a seedbed for other crops that will be grown before the lime-loving crop is planted.

A study of the readily available phosphorus in soils collected from different parts of Tulsa County indicates that phosphorus also is an important limiting factor in the production of maximum yields on a considerable percentage of the upland. Two hundred and eighty-eight samples of soil have been tested for readily available phosphorus. Of this number, 109 soils contained enough readily available phosphorus for the production of ordinary field crops, and phosphate fertilization would not give any economical returns on these areas; 31 contained a medium amount of readily available phosphorus, and these soils would respond to phosphorus fertilization for alfalfa and certain garden crops that have a high phosphorus requirement; 70 soils were low in this important element; and 78 were very low. Frequently soils that are very low in readily available phosphorus are also deficient in other plant nutrients, and their response to phosphorus fertilization will depend to a very great extent on the applica-

tion of other amendments, such as potash, nitrogen, and limestone, that may be needed for optimum development of plants.

Leguminous crops require a larger amount of readily available phosphorus for the production of maximum yields than do small grains or corn. The addition of a phosphate fertilizer to a leguminous crop will increase vegetative growth on a phosphorus-deficient soil, and any increase in yield will result in an increase in total nitrogen in the crop; consequently, in the development of a program for soil improvement, a farmer must decide whether a leguminous crop should benefit from the residual effect of fertilizers applied to previous crops to increase the yield of grain, or whether to apply a fertilizer at the time the leguminous crop is planted in order to increase the quantity of nitrogen added to the soil by increasing the yield of the legume. If rock phosphate is used in a cropping system, it should be applied to the leguminous crop, because grain crops, especially barley, do not utilize the phosphorus in rock phosphate as readily as that in superphosphate.

IMPORTANCE OF SOIL CONSERVATION PRACTICES

Soil conservation is an important problem on all areas of sloping land not protected by a vegetative cover during periods when torrential rainfall occurs. Comparatively smooth areas of bottom-land or terrace soils are not affected appreciably by soil erosion except at points where water may be concentrated and drop abruptly from higher to lower levels and thus cause gully erosion. On areas of upland that are planted continuously to small grain, using lespedeza for pasture and soil improvement, very little erosion can occur, because the surface of the land is protected by some form of organic matter throughout the season. On exceedingly long slopes, terrace ridges should be constructed to prevent the concentration of run-off in depressions, where gully erosion may develop, and to divert it from gently sloping areas of land on lower lying parts of the field where crops may suffer from too much water during seasons when more than average rainfall occurs. The disposal of water at terrace outlets must be given some consideration where water cannot be discharged onto areas of pasture land or meadow protected by a good growth of native grass. It may be necessary to construct special waterways or to convert a strip of cultivated land into a pasture or permanent meadow in order to carry run-off from higher to lower levels in such a manner that no damage will be done to the cultivated part of the field.

When row crops, such as corn or cotton, are grown, a large proportion of the land is exposed to the destructive effect of run-off at a time when maximum rainfall usually occurs. Unless these crops are planted on the contour and methods are used to prevent a concentration of the run-off, soil losses will take place. In many areas serious damage to surface soil already has reduced the productive capacity of many fields in this county. Attempts to improve the fertility of the soil by the addition of fertilizer or the growth of leguminous crops will be almost futile unless good soil management and cropping practices are adopted to protect the soil from the destructive effect of run-off. Sufficient demonstrations have been made in this area to

show the value of soil-conservation practices in connection with the development of better systems of soil management. Landowners who insist on maximum income and allow loss of capital to occur in the form of fertility carried away by run-off are following a short-sighted policy. Farm income depends to a very great extent on the productive capacity of land. If soils are allowed to deteriorate because of soil erosion or the use of cropping systems that gradually deplete fertility and nothing is done to replace it, not only will the farmer or landowner suffer because of decreased income, but the decline in fertility also will affect the welfare of the community, because of a decrease in farm purchasing power and land values, from which a considerable part of the taxes needed to operate local government is obtained.

CHEMICAL COMPOSITION OF TYPICAL SOIL PROFILES

The chemical composition of a number of important soil types occurring in Tulsa County is given in table 8. These soils are grouped in two divisions, and the different profiles are described elsewhere in this publication. Most of the samples have been collected from areas of virgin soil; consequently the quantity of nitrogen, organic matter, and other plant nutrients is higher than that occurring in cultivated fields adjacent to the area from which the samples were collected.

TABLE 8.—*Chemical composition of soils in Tulsa County, Okla.*

Soil type and sample number	Location	Depth	pH value	Total nitrogen	Organic matter	Total phosphorus	Readily available phosphorus
		Inches		*Percent*	*Percent*	*Percent*	*Parts per million*
SOILS OF THE UPLANDS							
Hanceville fine sandy loam:							
4033	NE¼SW¼ sec. 33, T. 19 N., R. 10 E.	0–5	6.3	0.053	1.35	0.012	2
4034		5–9	5.5	.042	.90	.012	2
4035		9–18	4.8	.042	.73	.013	2
4036		18–30	4.9	.017	.40	.009	2
4037		30–34	5.0	.014	.07	.006	2
Newtonia silty clay loam:							
4009	SE¼NE¼ sec. 4, T. 20 N., R. 14 E.	0–9	5.8	.151	3.30	.023	16
4010		9–18	5.7	.109	2.35	.020	6
4011		18–26	5.6	.109	1.90	.024	8
4012		26–48	5.7	.078	1.10	.021	8
4013		48–52	6.2	.078	.79	.026	12
Parsons silt loam:							
3983	SE¼SW¼ sec. 26, T. 17 N., R. 12 E.	0–15	5.7	.118	2.27	.011	0
3984		15–19	6.2	.081	1.71	.013	0
3985		19–21	6.3	.064	1.57	.013	0
3986		21–26	6.6	.064	1.55	.012	10
3987		26–35	6.9	.031	.98	.011	10
3988		35–47	7.1	.034	.53	.010	8
3989		47–60	7.6	.036	.37	.008	0
Summit silty clay loam:							
4044	SE¼NE¼ sec. 4, T. 19 N., R. 14 E.	0–12	5.8	.154	4.02	.022	12
4045		12–18	6.3	.111	3.17	.019	8
4046		18–24	6.7	.095	2.10	.017	8
4047		24–34	7.6	.077	2.20	.012	8
4048		34–40	8.0	.027	1.05	.021	8
SOILS OF THE TERRACES AND BOTTOM LANDS							
Lightning silty clay loam:							
4027	SE¼NW¼ sec. 9, T. 20 N., R. 13 E.	0–5	6.1	0.218	5.75	0.096	14
4028		5–11	6.2	.112	2.25	.048	8
4029		11–32	6.1	.103	1.59	.047	18
4030		32–60	6.9	.067	1.26	.038	18
4031		60–80	6.7	.056	.95	.039	38

TABLE 8.—*Chemical composition of soils in Tulsa County, Okla.*—Continued

SOILS OF THE TERRACES AND BOTTOM LANDS—Continued

Soil type and sample number	Location	Depth	pH value	Total nitrogen	Organic matter	Total phosphorus	Readily available phosphorus
		Inches		*Percent*	*Percent*	*Percent*	*Parts per million*
Lonoke very fine sandy loam:							
4039	SE¼SE¼ sec. 7, T. 17 N., R. 14 E.	0–10	6.4	0.098	2.60	0.039	80
4040		10–30	6.8	.048	1.40	.026	30
4041		30–38	6.8	.059	1.15	.021	28
4042		38–45	6.9	.077	.95	.026	44
4043		45–70	7.3	.118	.73	.036	112
Miller silty clay:							
4023	SE¼NW¼ sec. 30, T. 17 N., R. 14 E.	0–7	7.2	.176	3.93	.079	50
4024		7–28	7.3	.093	1.48	.058	48
4025		28–54	8.1	.059	1.05	.054	68
4026		54–64	8.2	.037	.50	.031	22
Stidham fine sandy loam:							
3993	NE¼NE¼ sec. 8, T. 17 N., R. 14 E.	0–10	6.9	.067	1.50	.015	10
3994		10–20	6.1	.076	1.45	.018	10
3995		20–34	5.6	.059	1.18	.017	10
3996		34–50	5.7	.048	.73	.020	4
3997		50–70	6.2	.039	.38	.018	4
Stidham fine sand:							
4005	NW¼NW¼ sec. 34, T. 18 N., R. 13 E.	0–5	6.3	.048	1.25	.011	32
4006		5–38	5.6	.019	.20	.010	28
4007		38–52	6.6	.014	.30	.018	50
4008		52–90	5.9	.017	.25	.015	32
Teller very fine sandy loam:							
3976	SE¼SE¼ sec. 26, T. 18 N., R. 13 E.	0–7	6.0	.148	3.23	.016	12
3977		7–20	5.9	.062	1.40	.009	6
3978		20–30	5.9	.067	1.25	.009	6
3979		30–38	5.9	.064	.95	.013	6
3980		38–50	6.0	.053	.60	.009	12
Verdigris very fine sandy loam:							
4016	SE¼SW¼ sec. 2, T. 20 N., R. 13 E.	0–4	6.4	.123	2.79	.047	12
4017		4–10	5.3	.056	.87	.029	12
4018		10–20	6.8	.034	.48	.022	12
4019		20–58	7.5	.028	.23	.018	38
4020		58–65	6.1	.067	1.30	.035	16
Yahola very fine sandy loam:							
3999	NE¼SW¼ sec. 3, T. 17 N., R. 13 E.	0–9	6.4	.126	2.90	.036	96
4000		9–28	7.2	.025	.38	.026	40
4001		28–35	7.9	.067	1.00	.039	24
4002		35–45	8.3	.039	.68	.032	48

All the upland soils that were studied are low in readily available phosphorus. Normally the Summit soils contain more readily available phosphorus than the analysis of Summit silty clay loam in table 8 indicates. The total phosphorus content of all these soils is low. This is a normal characteristic of the average soil of the upland in eastern Oklahoma, with the exception of a few soils that have developed in certain areas of weathered limestone, which is high in readily available and total phosphorus, such as the soils of the Summit and Leslie series. Some variation occurs in the acidity of these samples, but the reaction as shown in terms of pH values is typical of the soils in this general region.

A study of the composition of the soils collected from stream terraces and bottom lands indicates that most of these soils contain more readily available and total phosphorus than the soils of the uplands. This is especially true of the soils of the first bottoms, although the origin of the soil material in the Miller, Lonoke, and Yahola soils is decidedly different from that of the parent material on which the Lightning, Verdigris, and Stidham soils have developed. Except for the soils of the Stidham series, the nitrogen and organic-matter content of the bottom lands is higher than that occurring in

the upland soils. The reaction of the soils of the bottom lands indicates that the lime content of the majority of these soils is higher than that of the average soil of the uplands, although slight to medium acidity has developed in some of the soils of the terraces as a result of leaching by rainfall, which has not been sufficient to remove a very large percentage of the calcium from the younger soils occurring on the bottom lands. Samples of Teller very fine sandy loam were collected from an area of terrace land north of Bixby. This soil has been rather thoroughly leached to a depth of 5 feet. The porous character of the profile, combined with longer exposure to rainfall, as compared with soils developed on younger alluvium, is responsible for this condition.

On fertile areas of bottom land where vegetable crops are grown, the use of commercial fertilizers to maintain crop production may be the most economical procedure to follow. Where leguminous crops are grown to add nitrogen to the soil, the income from the land frequently is very low, compared with that from other crops; consequently the growth of a leguminous crop on soil that contains an abundant supply of mineral nutrients may not be a profitable procedure when the land and the vegetable crop have a high acre value. The cost of the nitrogen added by the legume will be high under such conditions unless exceedingly large yields can be produced. Under such conditions the purchase of a commercial form of nitrogen is less expensive than nitrogen obtained from the air by the leguminous crop.

As alfalfa will produce a comparatively high acre income on good land, this crop may be used to advantage in connection with the production of vegetable crops to maintain a favorable physical condition and also increase the nitrogen content of the soil. Where soil conditions are not favorable for the growth of alfalfa, winter cover crops or summer legumes, such as cowpeas, can be planted after a spring crop has been harvested. On very sandy soils where small grain is not a profitable crop, cowpeas and grain sorghums planted in alternate rows can be grown successfully for a considerable period if erosion is controlled and phosphorus fertilizer is applied in the row with the cowpeas each year, in order to increase the quantity of nitrogen that will be added to the soil by the cowpea crop.

MORPHOLOGY AND GENESIS OF SOILS

Tulsa County lies mainly within the great Prairie soil region of the United States and within the Osage Plains of the Central Lowland physiographic province, which lies east of the Great Plains. Small bodies of forested upland soils, locally known as cross timbers, belong to the Red and Yellow soils region, which covers southeastern United States.

Several geologic formations are exposed, from which soil parent materials have given rise to soils developed from sandstone, limestone, shale, and old unconsolidated sediments of alluvial origin. In the smooth areas these materials are deeply weathered, but on the hills and ridges they are near the surface and soil development is very slight.

The Parsons and Talihina soils have developed from shales under a prairie grass vegetation; the Bates soils, from sandstone or inter-

bedded sandstone and shale under a grass cover; the Collinsville soils, also from sandstones, into thin immature skeletal soils; the Hanceville soils, mainly from sandstone under a forest growth; the Summit, Denton, Crawford, and Newtonia soils, from limestone on the prairies; and the Teller, Dougherty, and Stidham soils, from old alluvial materials on high terraces, more or less eroded and rolling and lying high above the Arkansas River flood plain. Many kinds of alluvial soils occur on the flood plains of the streams.

Assuming that no marked changes in climatic environment have taken place in comparatively recent time, the soils of Tulsa County have been developed in a region of moderate precipitation—about 39 inches a year—and an average annual temperature of approximately 61° F., with mild short winters and long hot summers. The soils have been subject to considerable leaching as well as erosion, not only on the more rolling lands but also on the smooth prairie lands where the relief is very gentle.

For the most part, the Prairie soils are fairly dark, owing to the long-continued decay of tall prairie grasses, thereby favoring a moderate to fairly high accumulation of organic matter. The soils developed from shales are not so dark, because of imperfect underdrainage and oxidation, or so productive as the other soils developed under a cover of tall prairie grasses. The forested upland soils are light-colored and productive where deeply developed, but where shallow they are very low in productiveness. In general, the very dark and reddish-brown alluvial soils are the most highly productive, whereas the light-colored alluvial soils are the least productive.

The reaction of many of the upland soils is acid, although the soils developed from limestone are basic and, in places, calcareous. Those of alluvial origin, in general, are basic to calcareous, but a few are acid in reaction.

The Prairie soils that have undergone continued weathering for the longest time and have become stabilized under the impress of the climatic environment are the most mature and may be considered as normal. Pedologically, these are the most important soils in the county. They comprise the greater part of the deeply weathered Prairie soils (Bates and Parsons), and the predominant soil is Bates very fine sandy loam.

The following description of a typical profile of a virgin area of Bates very fine sandy loam was observed along the roadside about 400 feet east of the southwest corner of sec. 22, T. 21 N., R. 13 E.

(1) 0 to 11 inches, dark-brown very fine sandy loam with a single-grain structure. When moist the soil is very dark, but when dry it is dark brown with a slight grayish brown cast. Numerous grass roots of *Andropogon* species extend downward.

(2) 11 to 17 inches, dark-brown or brown fine-textured loam or silty clay loam with a crumbly structure. The slight variation in color is due mainly to workings of worms and insects and slight infiltrations from the layer above.

(3) 17 to 23 inches, brown or rather light brown friable crumbly silty clay loam or clay loam. Very small rust-brown, yellowish-brown, or reddish-brown specks and a slight infiltration of material from the layers above are apparent.

(4) 23 to 31 inches, light-brown, pale yellowish-brown, or brownish-yellow friable crumbly clay loam with a slight mottling of yellow, brown, and reddish brown. The faint reddish-brown specks or mottlings con-

tain little or no clay material. A few sandstone fragments are present in the lower part.

(5) 31 to 40 inches, brownish-yellow crumbly clay loam containing a considerable quantity of partly disintegrated soft sandstone fragments interbedded with intervening slightly mottled clay material.

All the above layers are noncalcareous.

The soil in the smoother prairie areas, where the surface is only slightly undulating to almost flat, is formed mainly from shale materials, which give rise to a more highly acid soil with an extremely tough heavy subsoil, or claypan. The greater part of this soil is designated as Parsons silt loam. This soil is representative in Oklahoma and especially in southeastern Kansas and has reached a more advanced stage of development than any of the other Prairie soils in the county, with the possible exception of the Cherokee soils.

A typical profile of Parsons silt loam observed about 500 feet west of the half-mile corner in a roadside pit in the SE¼ sec. 26, T. 17 N., R. 12 E., is described as follows:

(1) 0 to 15 inches, dark grayish-brown silt loam that has a single-grain crumbly structure and contains a rather high percentage of very fine sand. The material is sod-bound with numerous prairie-grass roots.

(2) 15 to 19 inches, grayish-brown very fine sandy loam that is slightly lighter colored than the material in the layer above and has a single-grain structure. A slight fine sprinkling of gray material is noticeable.

(3) 19 to 21 inches, grayish-brown variable-textured material, generally a clay loam. This layer is transitional and has a crumbly granular structure.

(4) 21 to 26 inches, grayish-brown or brown waxy dense clay with considerable rust-brown, dark-brown, and gray mottling. Numerous semihard pellets, ranging from one-tenth to one twenty-fifth inch in diameter, are noticeable. The structure is decidedly blocky.

(5) 26 to 35 inches, brown or olive-brown dense clay with numerous rust-brown mottlings and dark-brown pellets, as in the layer above. This and the layer above constitute the layers of maximum density.

(6) 35 to 47 inches, olive-gray or grayish-green heavy clay containing numerous small fragments of gypsum, which are noticeable when the layer is cut with a spade. Dark-brown pellets and blocky structure are present as in the two layers above.

(7) 47 to 60 inches, light olive-gray, yellowish-gray, or grayish-brown clay mottled with rust-brown material. Numerous pellets are present like those in the three layers above, but their size is noticeably larger—some as much as one-fourth inch in diameter.

(8) 60 to 70 inches, grayish-brown clay, in which the color and texture are lighter and rust-brown mottlings are fewer than in the overlying material. Some brown shale fragments are in the lower part of this layer. The structure is blocky.

All the above layers are more or less acid.

Associated with the Bates and Parsons soils are two Prairie soils developed from limestone, which have similar profile characteristics but a less mature profile than the Parsons soils. These soils are members of the Newtonia and Summit series. The general characteristics of these soils are much the same, except that the Newtonia soils are somewhat red in contrast to the dark color of the Summit soils.

Following is a description of a profile of Summit silty clay loam observed in the SE¼NE¼ sec. 4, T. 19 N., R. 14 E.:

(1) 0 to 12 inches, dark grayish-brown uniform silty clay loam having a fine-granular structure. Numerous grass roots bind the soil firmly.

(2) 12 to 18 inches, dark grayish-brown crumbly heavy silty clay loam containing a few scattered soft rounded small pellets averaging about one twenty-fifth inch in diameter.

(3) 18 to 24 inches, dark-gray silty clay containing a few small pellets as in the layer above. When dry the material crumbles into aggregates of rather sharp granular structure, and some vertical cracks form during prolonged droughts.
(4) 24 to 34 inches, gray clay with a slight brownish hue, containing numerous light-brown and olive-colored mottlings. Small pellets are present as in the layers above.
(5) 34 to 40 inches, gray or olive-gray clay as in the layer above, intermixed with fragmentary limestone rock material, which overlies gray calcareous limestone rock.

In many places limestone rock lies at a greater depth than in the profile described, and in other places it is absent, apparently having completely disintegrated.

The Talihina soils also have a prairie cover, but they are derived mainly from noncalcareous shales. Various quantities of hard sandstone slabs are strewn over the surface. The parent shale material is olive gray, has a thin platy structure, and forms a heavy slick greaselike clay.

The light-colored soils under forest vegetation occupy rather small areas. Those developed from sandstone are, for the most part, very thin and stony and belong to the Hanceville and Hector series. Among these soils the most normally developed one is Hanceville fine sandy loam. The area of this soil is small. Most of the soils of these two series are so rolling that erosion keeps pace with weathering, only a thin layer of soil material accumulates, and more or less rocky material is exposed on the surface.

The forested soils developed from thick beds of old stream sediments comprising sandy clay beds are developed on high ancient terraces and are chiefly brown soils and grayish-brown soils of the Teller, Dougherty, and Stidham series. In smooth areas these soils develop deeply, but in sloping areas the soils are eroded, gullied, and thin. The Teller soils are smooth, deep, friable, and largely sandy, with reddish-brown or brownish-red sandy clay subsoils. The Stidham soils are similar in physical characteristics but have light-brown or brownish-yellow subsoils. The Dougherty soils seem to be old eroded and leached phases of Teller soils.

The alluvial soils of the county are varied and belong to several series. Those of the Arkansas River flood plain that are reddish-brown and calcareous belong to the Miller and Yahola series. They are formed from overflow deposits transported from the "Red Beds" of western Oklahoma. They differ mainly in that the Miller soils have dull-red heavy clay subsoils, whereas the Yahola soils consist of light reddish-brown material and are sandy throughout the subsoil.

The Lonoke series comprises brown soils of the high-bottom benches of the Arkansas River, which are rarely overflowed. These soils, although not generally calcareous, are only slightly acid and have a calcareous substratum. They are made up largely of soil materials washed from the dark soils of the western plains areas. The Brewer soils are very dark slowly drained soils with dark-gray subsoils.

The Perry soils occupy imperfectly drained areas where water stands for considerable periods. These soils are more or less leached, having somewhat gray surface soils and mottled gray subsoils, but the lower part of the subsoils and substrata are somewhat red and calcareous.

The Verdigris soils comprise brown crumbly friable soils of high well-drained flood plains along streams draining the prairies north of this county. The soil materials have been transported from eroded areas of smooth dark Prairie soils, such at the Bates, Parsons, and Summit soils. Associated with the Verdigris soils, but much more poorly drained, are gray or grayish-brown soils of the Lightning series. Other soils bordering streams that drain the dark Summit soils are very dark and black and are included in the Osage series.

SUMMARY

Tulsa County is in the northeastern part of Oklahoma, the fourth county from the eastern and second county from the northern State line. The total area is 585 square miles. This county lies mainly within the Prairie soil region of the United States. Physiographically, it is a part of the Osage Plains of the Central Lowland, which lies east of the Great Plains.

The surface features are those of a comparatively smooth prairie in the northern, eastern, and southern parts, interspersed with moderately hilly land in the northwestern and extreme southeastern parts, whereas most of the western part is hilly to moderately broken. The elevation of the county ranges from 550 to 1,017 feet.

The Arkansas River, which flows southeastward, drains the western and southern parts; and Bird Creek and its tributaries drain most of the northern part. Surface drainage ordinarily is good to excessive, but underdrainage is slow in places on the smooth prairies.

The county was organized in 1907. In 1930 the total population was 187,574; the rural population was 39,642, with an average density of 67.8 persons per square mile. Tulsa, the county seat, had a population of 141,258 in 1930.

The mean annual precipitation is 38.81 inches, the mean annual temperature is 60.7° F., and the average frost-free period 219 days.

The agriculture consists mainly of diversified farming, dairying, and truck farming. About 50 percent of the land is arable, and the rest is nonarable and used mainly for grazing livestock. Corn is the most important crop, followed by oats, cotton, sorghums, wheat, tame hay, and alfalfa. Many kinds of truck crops are grown in the Arkansas River Valley, largely for local markets.

As the soils of the county differ widely in physical and chemical characteristics they have a wide range of agricultural adaptability. They have been placed in seven groups based on similar general soil characteristics and their most common use. Several of them are unsuited for cultivated crops.

Group 1 consists of smooth-lying Prairie soils with moderately heavy textured subsoils. They are members of the Bates, Fitzhugh, Summit, and Newtonia series and occupy many widely separated areas. Their parent materials are derived mainly from sandstone and limestone. These soils are used for general farming and are well suited to the production of corn, hay, forage crops, cotton, small grains, fruits, and vegetables. About 75 percent of these soils is cultivated.

Group 2 comprises Prairie soils with dense clay subsoils (Planosols) on smooth upland plains. They are grayish-brown acid soils developed largely from shale and are included in the Parsons and

Cherokee series. These also are used for general farming but are best suited to the production of small grains, grasses, and forage crops. The heavy claypan subsoils restrict underdrainage and thereby lower the range of crops to which the soils are suited. About 70 percent of these soils is cultivated.

Group 3 comprises the well-drained alluvial soils of the Arkansas River flood plain and smaller stream bottoms, and they are, for the most part, very favorable for the production of a wide range of crops. The Miller, Yahola, Brewer, Osage, Lonoke, and Verdigris soils are highly productive for corn, cotton, alfalfa, sorghums, small grains, various truck and garden crops, and orchard crops. Approximately 95 percent of these soils is cultivated.

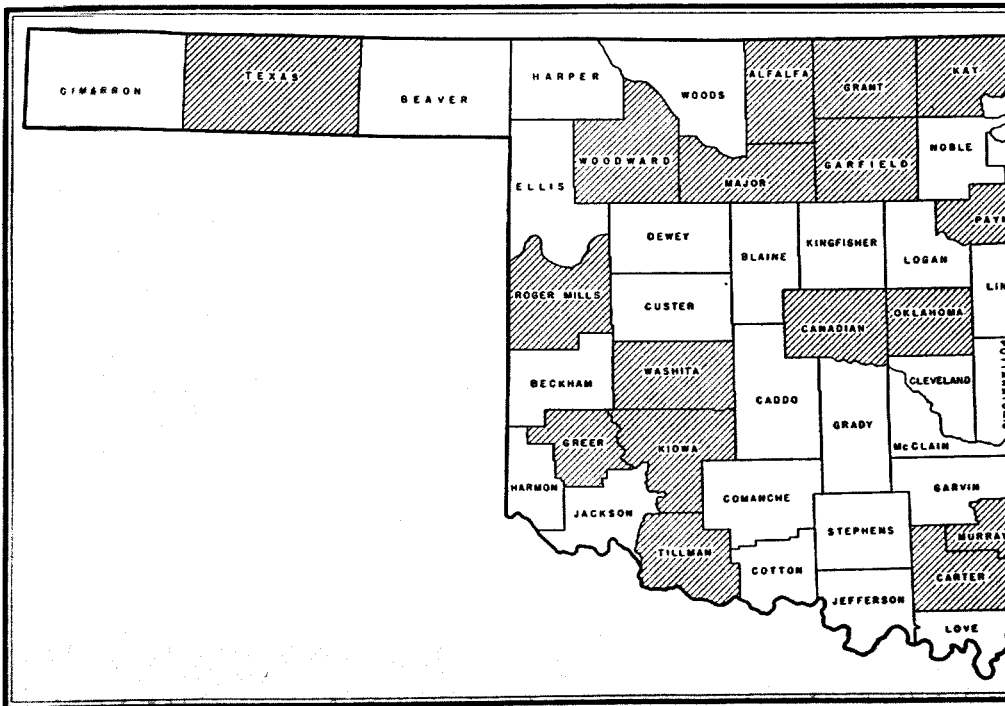
The poorly drained alluvial soils of group 4 are best suited for grazing in their present condition, and only 15 percent of them is cultivated. The Lightning and Perry soils make up this group.

Group 5 consists of forested upland soils with friable subsoils. These are, for the most part, light-colored and sandy-textured and have loose permeable subsoils. They are fairly productive and well suited to corn, cotton, sorghums, various other feed crops, and especially truck and orchard crops, such as peaches, apples, and pears. They are more or less susceptible to erosion and drifting and require careful management. These soils are of the Teller, Dougherty, and Stidham series and occupy high terraces. The Hanceville soils are developed from sandstone parent materials.

Group 6, soils generally unsuited for cultivation, includes members of the Stidham, Talihina, Collinsville, Yahola, and Verdigris series that are too rolling, steep, sandy, and thin to produce good yields of the various crops. These are, therefore, the least productive of the arable soils of the county.

The nonarable soils and miscellaneous land types in group 7 have little agricultural value except for grazing and to a slight extent for the production of fuel and posts. The stony Prairie soils of the Collinsville, Denton, Crawford, and Talihina series are the most valuable for grazing, whereas the stony soils of the Hector series and rough gullied land are the least valuable for this use. Such land types as mine dumps and riverwash have practically no value, even for grazing.

○



Areas surveyed in Oklahoma, shown by shading.

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BUREAU OF CHEMISTRY AND SOILS
HENRY G. KNIGHT, CHIEF
SOIL SURVEY DIVISION, CHARLES E. KELLOGG, CHIEF

SOIL MAP
TULSA COUNTY
OKLAHOMA

OKLAHOMA AGRICULTURAL EXPERIMENT STATION
C. P. BLACKWELL, DIRECTOR
AGRONOMY DEPARTMENT
H. J. HARPER, PROFESSOR OF SOILS

LEGEND

PRAIRIE SOILS OF THE UPLANDS

FRIABLE SOILS (On sandstone)

- Bates fine sandy loam — By
- Bates very fine sandy loam — Bf
- Deep phase — Bf
- Bates silt loam — Ba
- Fitzhugh very fine sandy loam — Fv

SOILS WITH CLAYPAN (On sandstone and shales)

- Cherokee very fine sandy loam — Ch
- Parsons silt loam — Ps
- Deep phase — Ps
- Slope phase — Ps

SHALLOW AND STONY (On sandstone)

- Collinsville stony fine sandy loam — Cs
- Collinsville very fine sandy loam — Cv

FRIABLE SOILS (On limestone)

- Newtonia fine sandy loam — Nf
- Newtonia silty clay loam — Ns

SHALLOW AND STONY (On limestone)

- Crawford stony loam — Cl
- Denton stony clay loam — Ds

SOILS WITH HEAVY SUBSOILS (On limestone and shale)

- Summit silty clay loam — Ss
- Summit clay — Sc

SHALLOW AND STONY (On shales)

- Talihina silty clay loam — Ts
- Talihina stony clay loam — Tm

FORESTED SOILS OF THE UPLANDS

FRIABLE SOILS (On sandstone)

- Hanceville fine sandy loam — Hf

SHALLOW AND STONY (On sandstone)

- Hector stony fine sandy loam — Hs
- Rough stony land, Hector soil material — RsH

FORESTED SOILS OF THE TERRACES

LIGHT GRAY AND YELLOW (Old alluvium)

- Dougherty very fine sandy loam — Dv
- Stidham fine sand — St
- Stidham loamy fine sand — Sd
- Stidham fine sandy loam — Sf
- Stidham very fine sandy loam — Sv

BROWN AND DARK GRAY

- Brewer silty clay loam — Bs
- Brewer silty clay — Br
- Teller very fine sandy loam — Tv

FORESTED SOILS OF THE BOTTOMS AND LOW TERRACES

WELL-DRAINED (Alkaline sediments)

- Lonoke very fine sandy loam — Lv
- Miller loam — Ml
- Miller silty clay — Ms
- Yahola loamy fine sand — Yf
- Yahola loamy very fine sand — Yl
- Yahola very fine sandy loam — Yv

POORLY DRAINED (Acidic sediments)

- Perry clay — Pc

WELL-DRAINED (Acid sediments)

- Verdigris loamy fine sand — Vl
- Verdigris very fine sandy loam — Vv
- Verdigris loam — Vm
- Verdigris silty clay loam — Vc

POORLY DRAINED (Acid sediments)

- Lightning silty clay loam — Lc
- Lightning silty clay — Ls
- Osage silty clay loam — Os
- Osage silty clay — Oc

MISCELLANEOUS

- Riverwash — Rv
- Rough gullied land — Rg
- Mine dumps
- Saline spots — S

CONVENTIONAL SIGNS

CULTURE (Printed in black)

- City or Village, Roads, Buildings, Wharves, Jetties, Breakwater, Levee, Lighthouse, Fort
- Secondary roads and Trails
- Railroads: Steam and Electric
- Bridges, Ferry
- R.R. crossings, Tunnel
- Ford, Dam, Sawmill, Windmill
- Boundary lines: State, County, Civil Township
- School, Church, Creamery, Cemeteries
- Boundary lines: Reservation, Land Grant, City or Village
- Triangulation station, Boundary monument, Oil or Gas wells
- U.S. township and Section lines, Recovered corners
- Forest fire station, Airway beacon, Oil or Gas tanks
- Transmission line, Oil or Gas pipe line
- Mine or Quarry, Rock outcrop, Made land
- Soil boundaries, Stony, Gravelly and Cherty areas

RELIEF (Printed in brown or black)

- Contours, Depression contours
- Prominent Hills, Mountain Peaks
- Sand, Wash, and Sand dunes
- Bluff, Escarpment, Mine dumps

DRAINAGE (Printed in blue)

- Streams, Springs, Wells, Flowing wells
- Lakes, Ponds, Intermittent lakes
- Unsurveyed and Intermittent streams
- Water-pipe lines, Canals, Ditches, Flumes
- Swamp, Salt marshes
- Submerged marsh, Tidal flats

The above signs are in current use on the soil maps. Variations from this usage appear in some maps of earlier dates.

W. T. Carter, Inspector, District 4.
Soils surveyed by E. W. Knobel, U. S. Department of Agriculture, in charge, and O. H. Brensing, Oklahoma Agricultural Experiment Station.

Scale 1 inch=1 mile
1 ½ 0 1 2 3 Miles

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